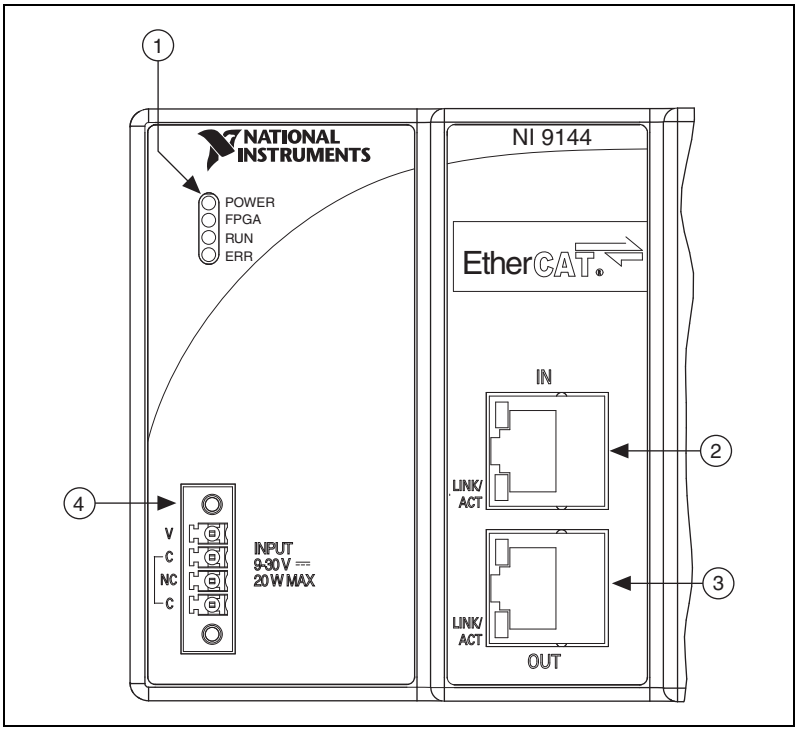
USER GUIDE AND SPECIFICATIONS

NI 9144

Deterministic Ethernet Expansion Chassis for C Series Modules

This user guide describes how to connect the NI 9144 chassis to a network, how to use the NI 9144 chassis features, and contains the NI 9144 chassis specifications. The NI 9144 is a slave device and requires a compliant EtherCAT Master and network to function.



1	LEDs	3	OUT Port
2	IN Port	4	Power Connector

Figure 1. NI 9144 Chassis

NATIONAL INSTRUMENTS

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Safety Guidelines

Operate the NI 9144 chassis only as described in this user guide.

Safety Guidelines for Hazardous Locations

The NI 9144 chassis is suitable for use in Class I, Division 2, Groups A, B, C, D, T4 hazardous locations; Class 1, Zone 2, AEx nA IIC T4 and Ex nA IIC T4 hazardous locations; and nonhazardous locations only. Follow these guidelines if you are installing the NI 9144 chassis in a potentially explosive environment. Not following these guidelines may result in serious injury or death.

Caution Do *not* disconnect the power supply wires and connectors from the chassis unless power has been switched off.

Caution Substitution of components may impair suitability for Class I, Division 2.

Caution For Zone 2 applications, install the system in an enclosure rated to at least IP 54 as defined by IEC 60529 and EN 60529.

Special Conditions for Hazardous Locations Use in Europe

This equipment has been evaluated as Ex nA IIC T4 equipment under DEMKO Certificate No. 07 ATEX 0626664X. Each chassis is marked ⟨Ex⟩ II 3G and is suitable for use in Zone 2 hazardous locations, in ambient temperatures of $-40 \leq Ta \leq 70$ °C.

Electromagnetic Compatibility Guidelines

This product was tested and complies with the regulatory requirements and limits for electromagnetic compatibility (EMC) as stated in the product specifications. These requirements and limits are designed to provide reasonable protection against harmful interference when the product is operated in its intended operational electromagnetic environment. There is no guarantee that interference will not occur in a particular installation. To minimize the potential for the product to cause interference to radio and television reception or to experience unacceptable performance degradation, install and use this product in strict accordance with the instructions in the product documentation.

The following statements contain important information needed before installing and using this product:

Caution This product is intended for use in industrial locations. As a result, this product may cause interference if used in residential areas. Such use must be avoided unless the user takes special measures to reduce electromagnetic emissions to prevent interference to the reception of radio and television broadcasts.

Caution This product may become more sensitive to electromagnetic disturbances in the operational environment when test leads are attached or when connected to a test object.

Caution Emissions that exceed the regulatory requirements may occur when this product is connected to a test object.

Caution Changes or modifications not expressly approved by National Instruments could void the user's authority to operate the hardware under the local regulatory rules.

Special Guidelines for Marine Applications

Some products are Lloyd's Register (LR) Type Approved for marine (shipboard) applications. To verify Lloyd's Register certification for a product, visit `ni.com/certification` and search for the LR certificate, or look for the Lloyd's Register mark on the product label.

Caution In order to meet the EMC requirements for marine applications, install the product in a shielded enclosure with shielded and/or filtered power and input/output ports. In addition, take precautions when designing, selecting, and installing measurement probes and cables to ensure that the desired EMC performance is attained.

Mounting the NI 9144 Chassis

You can mount the chassis in any orientation on a 35 mm DIN rail or on a panel. Use the DIN rail mounting method if you already have a DIN rail configuration or if you need to be able to quickly remove the chassis. Use the panel mount method for high shock and vibration applications.

Caution Your installation must meet the following requirements for space and cabling clearance:

- Allow 25.4 mm (1 in.) on the top and the bottom of the chassis for air circulation.
- Allow 50.8 mm (2 in.) in front of C Series I/O modules for cabling clearance for common connectors, such as the 10-terminal, detachable screw terminal connector, as shown in Figure 2.

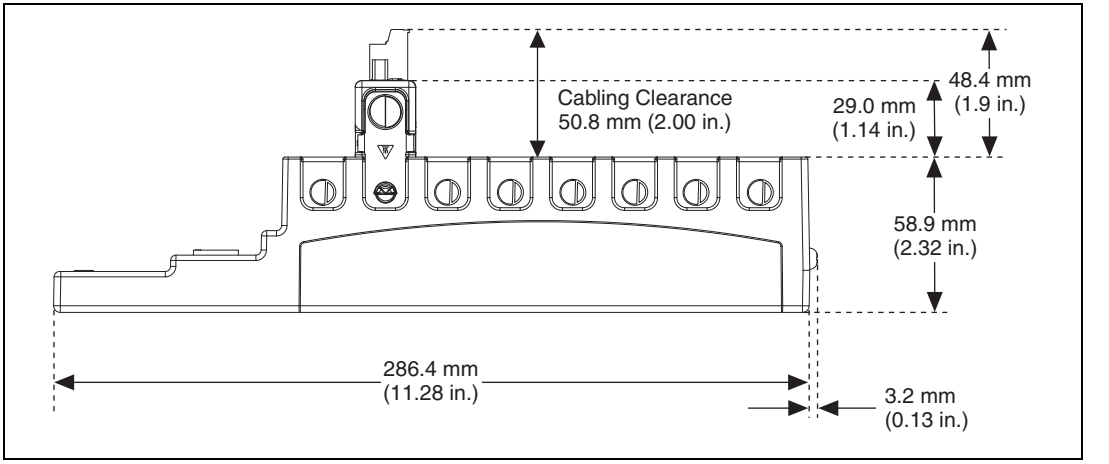


Figure 2. NI 9144 Chassis, Bottom View with Dimensions

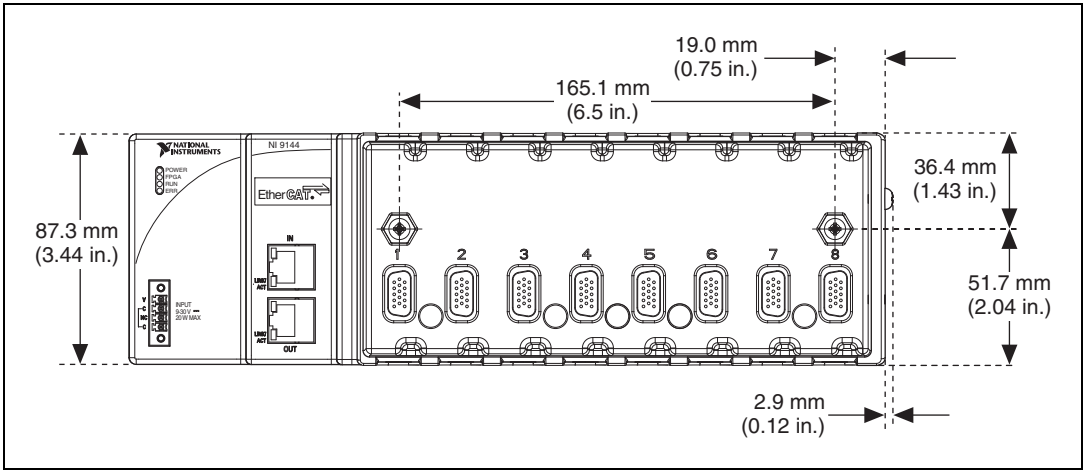


Figure 3. NI 9144 Chassis, Front View with Dimensions

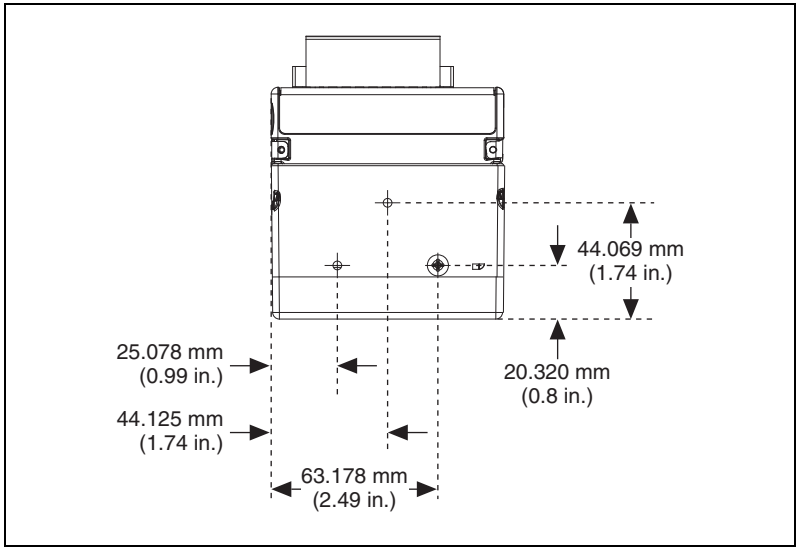


Figure 4. NI 9144 Chassis, Side View with Dimensions

The following sections contain mounting instructions. Before using any of these mounting instructions, record the serial number from the back of the chassis. After the chassis is mounted, you will not be able to read the serial number.

Caution Remove any C Series I/O modules from the chassis before mounting it.

Mounting the NI 9144 Chassis on a Panel

Use the NI 9905 panel mount kit to mount the NI 9144 chassis on a flat surface. To use the NI 9905 panel mount kit, complete the following steps:

1. Fasten the chassis to the panel mount kit using a number 2 Phillips screwdriver and two M4 × 16 screws. National Instruments provides these screws with the panel mount kit. You *must* use these screws because they are the correct depth and thread for the panel.

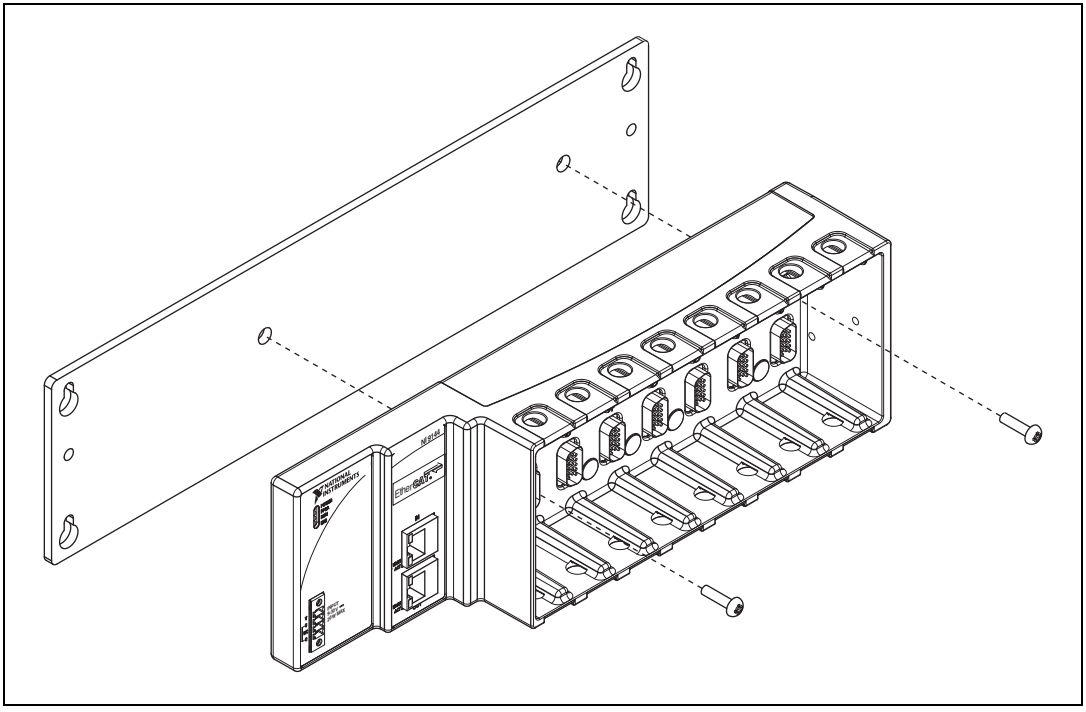


Figure 5. Installing the Panel Mount Accessory on the NI 9144 Chassis

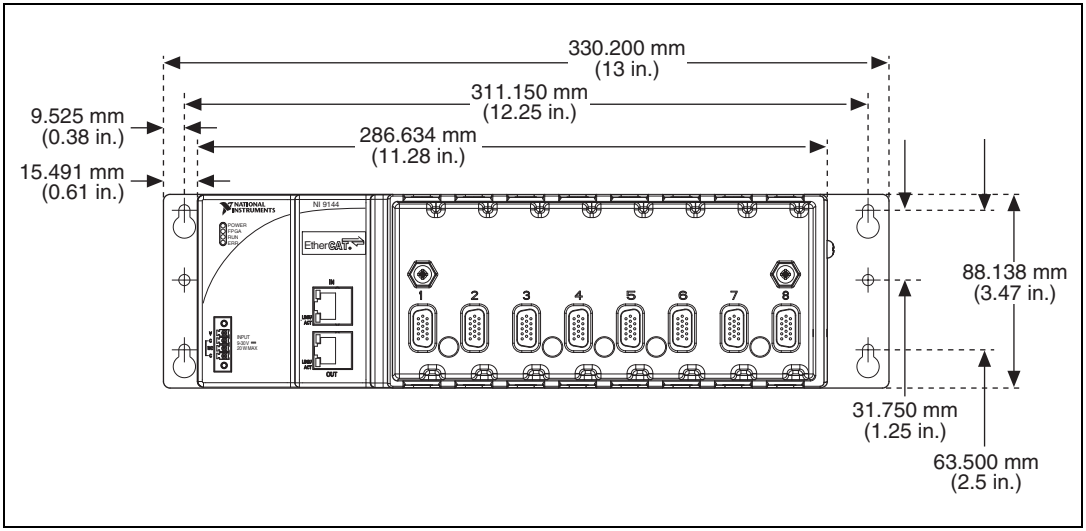


Figure 6. Dimensions of NI 9144 Chassis with Panel Mount Accessory Installed

2. Fasten the NI 9905 panel to the wall using the screwdriver and screws that are appropriate for the wall surface.

Caution Remove any C Series I/O modules from the chassis before removing it from the panel.

Mounting the Chassis on a DIN Rail

Caution Remove any C Series I/O modules from the chassis before removing the chassis from the DIN rail.

Use the NI 9915 DIN rail mount kit if you want to mount the chassis on a DIN rail. You need one clip for mounting the chassis on a standard 35 mm DIN rail. Complete the following steps to mount the chassis on a DIN rail:

1. Fasten the DIN rail clip to the chassis using a number 2 Phillips screwdriver and two M4 × 16 screws. National Instruments provides these screws with the DIN rail mount kit.

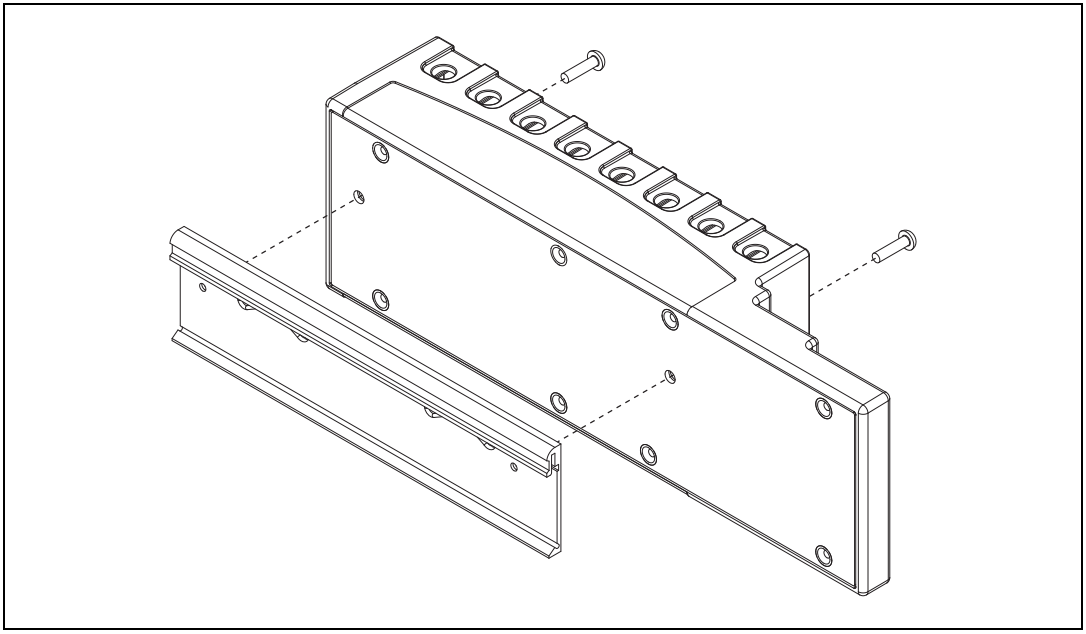
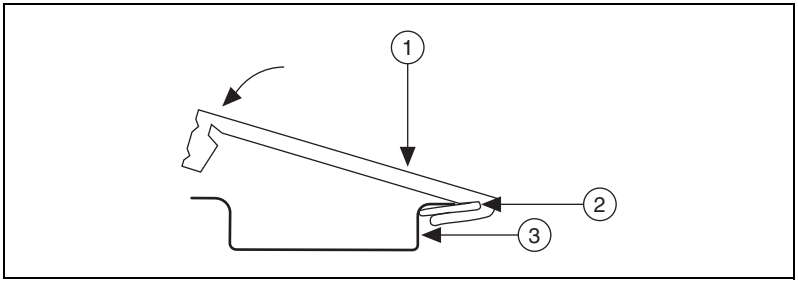


Figure 7. Installing the DIN Rail Clip on the NI 9144 Chassis

2. Insert one edge of the DIN rail into the deeper opening of the DIN rail clip, as shown in Figure 8.



1	DIN Rail Clip	2	DIN Rail Spring	3	DIN Rail

Figure 8. One Edge of the DIN Rail Inserted in a Clip

3. Press down firmly on the chassis to compress the spring until the clip locks in place on the DIN rail.

Connecting the NI 9144 Chassis to a Network

NI recommends that you install a private network segment for your deterministic Ethernet expansion devices. Slave devices cause network flooding on a standard network. Non-EtherCAT frames jeopardize the system performance and determinism on an EtherCAT network. Refer to the EtherCAT Technology Group Web site at `www.ethercat.org` for more information.

The following devices are required to connect the NI 9144 chassis to a network successfully: a host computer, a supported LabVIEW Real-Time target[1] with the NI-Industrial Communications for EtherCAT software driver installed on it, and an NI 9144 slave device.

To have your LabVIEW target establish a connection with the NI 9144 chassis, connect the secondary port of the LabVIEW Real-Time target to the NI 9144 IN port. Use a standard Category 5 (CAT-5) or better Ethernet cable. Use the NI 9144 OUT port to connect to other NI 9144 chassis and slave devices on the same segment.

Once the connection is established, install the NI-Industrial Communications for EtherCAT software on the host computer and then use Measurement & Automation Explorer (MAX) to install the NI-Industrial Communications for EtherCAT driver on the target. Your NI 9144 comes pre-programmed to use the RIO Scan engine. If you want to program the FPGA with your own custom logic, use LabVIEW FPGA.

Caution To update your firmware on the NI 9144 chassis, refer to the *Updating Your Firmware* section of this user guide.

Caution To prevent data loss and to maintain the integrity of your EtherCAT installation, do *not* use a CAT-5 Ethernet cable longer than 100 m. National Instruments recommends using a CAT-5 or better shielded twisted-pair Ethernet cable. To build your own cable, refer to the *Cabling* section for more information about Ethernet cable wiring connections.

Note If you are not using a LabVIEW Real-Time target as the master controller, consult your product documentation about networking connections.

[1] For supported LabVIEW targets, refer to `ni.com/info` and enter `ecatmaster`.

Understanding LED Indications

Figure 9 shows the NI 9144 chassis LEDs.

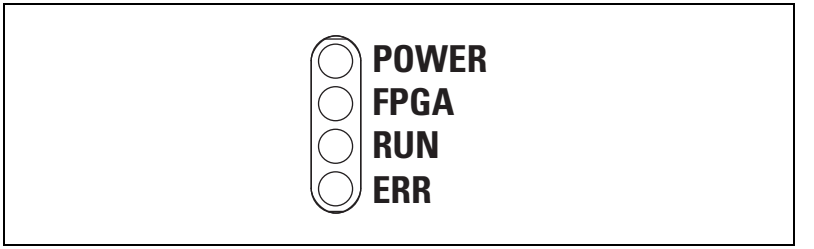


Figure 9. NI 9144 Chassis LEDs

POWER LED

The POWER LED is lit when the NI 9144 chassis is powered on. This LED indicates that the power supply connected to the chassis is adequate.

FPGA LED—Open FPGA Mode Only

You can program this LED using LabVIEW FPGA.

RUN and ERR LEDs

The RUN LED is green and indicates that the NI 9144 is in an operational state. The ERR (error) LED is red and indicates an error. Table 1 lists the RUN and ERR LED indications.

Table 1. RUN and ERR LED Indications

LED Behavior	RUN LED		ERR LED	
	Run Mode	Description	Error Mode	Description
Off	INIT (Initialize)	Slave discovery and initialization	No Error	—
Blinking	PRE-OP (Pre-Operational)	Module detection, configuration, and synchronization	Invalid Configuration	Unsupported module, bad device profile, object dictionary, and configuration
Single-Flash	SAFE-OP (Safe Operational)	Inputs are functional, outputs drive constant safe values	Unsolicited State Change	Backplane or module emergency condition

Table 1. RUN and ERR LED Indications (Continued)

LED Behavior	RUN LED		ERR LED	
	Run Mode	Description	Error Mode	Description
Double-Flash	—	—	Application Watchdog Timeout	Slave did not receive a scheduled EtherCAT telegram
On	Operational	Inputs and outputs are functional	PDI (Process Data Interface) Watchdog Timeout	Slave failed to transfer I/O data in scheduled time
Flickering	Bootstrap	Firmware update	Booting Error	Corrupt firmware or hardware error

Figure 10 shows the Run Mode transition.

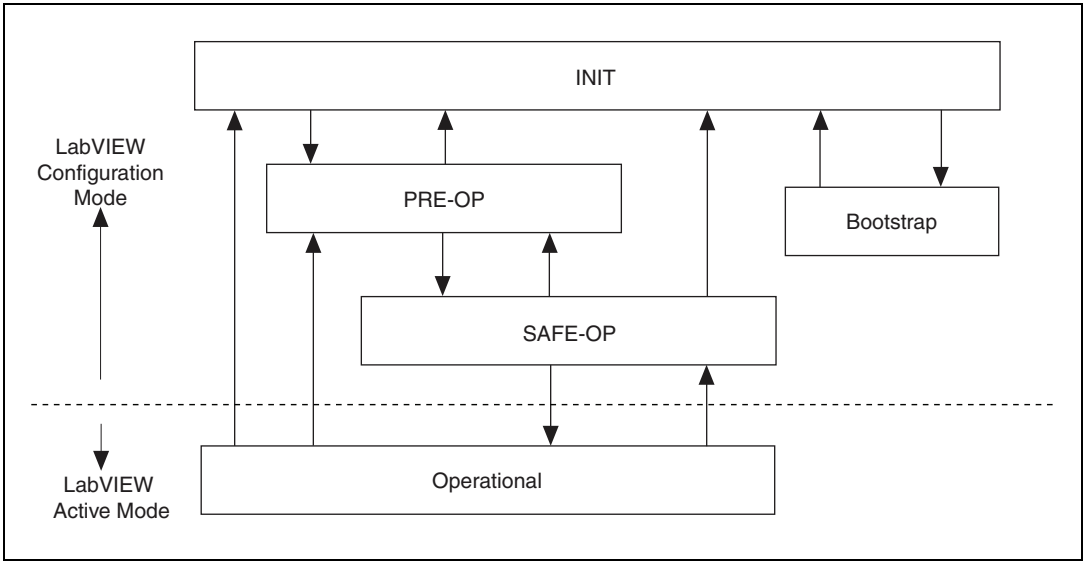


Figure 10. EtherCAT Modes

Resetting the NI 9144 Network Configuration

To reset the NI 9144 network configuration, unplug and replug in the NI 9144 chassis.

Safe-State Outputs

The NI 9144 has a safe state that lies between its configuration and operational states. When moving out of the LabVIEW Active Mode to the LabVIEW Configuration Mode, during normal operation or in case of a serious error, the NI 9144 passes through this EtherCAT safe state.

The EtherCAT safe state forces the data of output modules to pre-defined safe values, which are set by default to output zero volts for the default channel configuration. It is possible to change the safe values as needed by writing to the appropriate object dictionary entries for your output module.

Slave Timing Modes

The NI 9144 can operate in two fundamental timing modes: free-run and synchronized using the EtherCAT distributed clock (DC) through DC synchronized mode.

In free-run mode the NI 9144, by default, runs its conversion cycle as quickly as the slowest module allows. It is possible to slow the free-run conversion cycle down by writing a minimum cycle time in nanoseconds to the NI 9144's index 0x3001.1.

In DC synchronized mode the NI 9144 begins each conversion cycle on a signal from the EtherCAT Master/scan engine. If the external cycle time is too fast for the given module configuration, the NI 9144 signals an error. The NI Indcom for EtherCAT only supports DC mode of operation.

Updating Your Firmware

Firmware updates are performed by way of the File over EtherCAT (FoE) download protocol. All NI factory firmware update files have a `.foe` extension and have internal identification information that guides the NI 9144 during the update. Refer to your specific master software documentation for the procedure of sending FoE downloads.

The NI 9144 firmware update does not use the filename or password information.

You may also use this utility to download custom FPGA projects with a `.lvbitx` extension.

How to Upgrade Your Firmware

To upgrade your firmware to a new version or reset your device to the factory state, complete the following steps:

1. Discover your real-time target and NI 9144 chassis.
2. Right-click the RT target and select **Deploy All**, as shown in Figure 11.

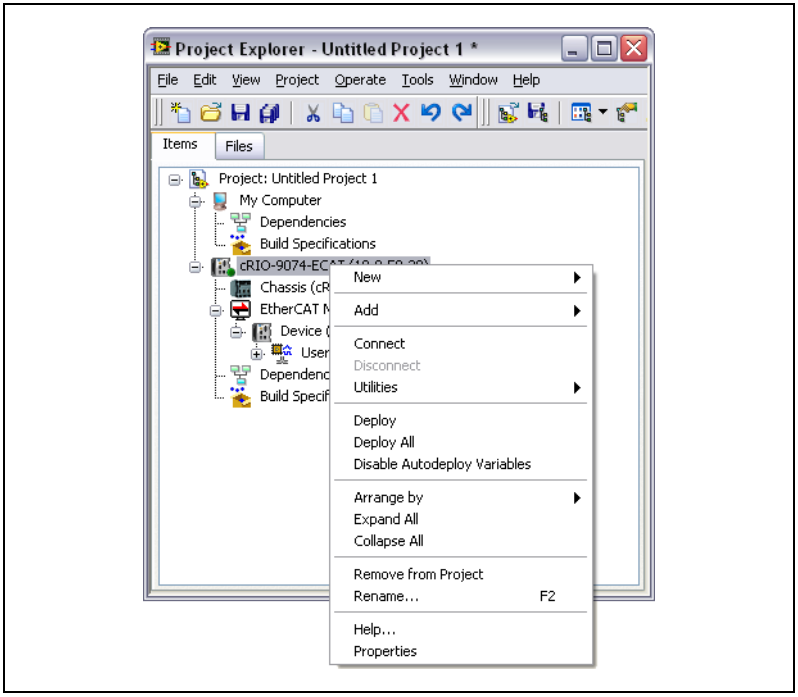


Figure 11. Deploy All

3. After a successful deployment, change the controller to Configuration Mode. Right-click the RT target and select **Utilities»Scan Engine Mode»Switch to Configuration**, as shown in Figure 12.

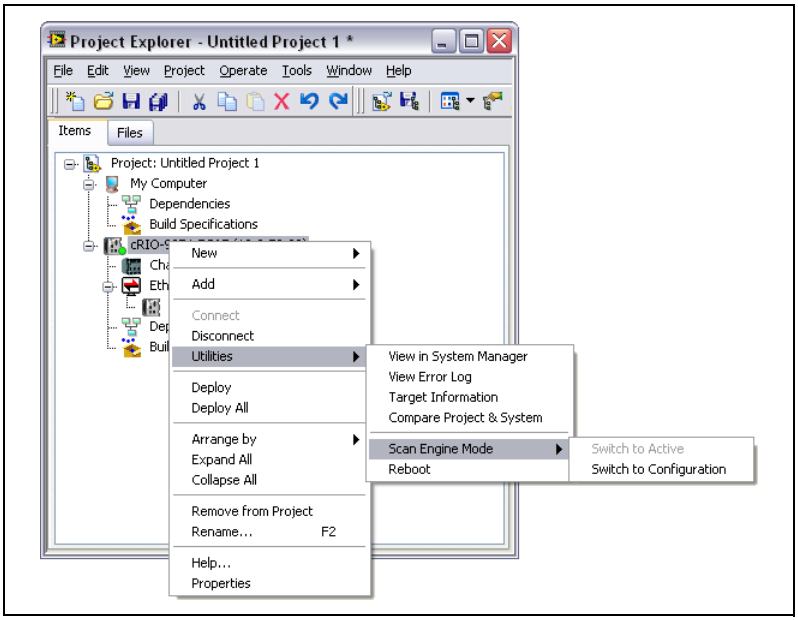


Figure 12. Switch to Configuration

4. Right-click the NI 9144 that requires a firmware change and select **Online Device State**, as shown in Figure 13.

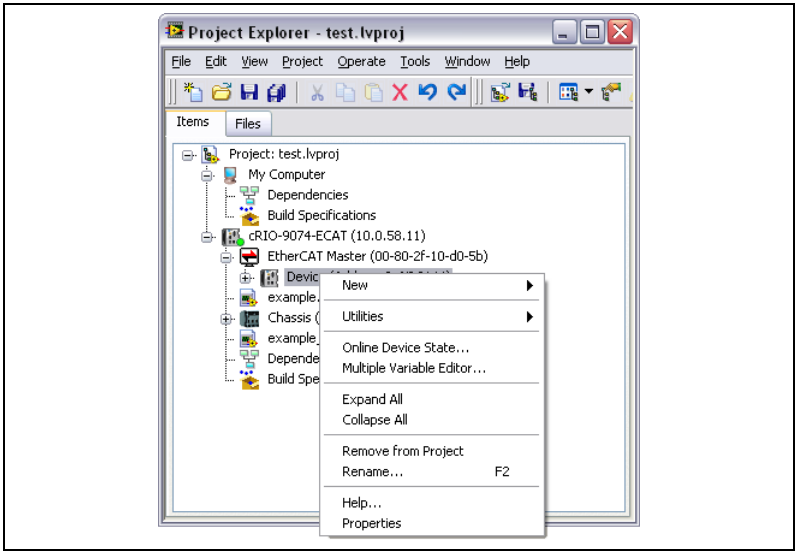


Figure 13. Online Device State

5. Change the online state by clicking the **Init** button and then clicking the **Bootstrap** button, as shown in Figure 14.

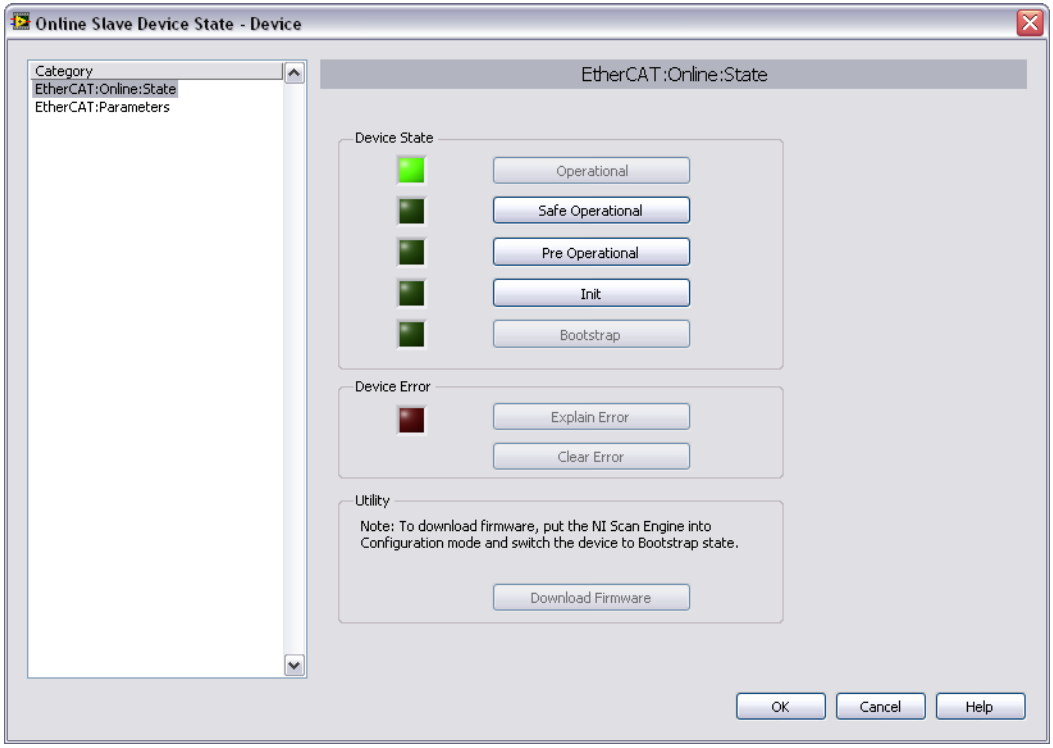


Figure 14. Clicking Bootstrap

6. Click the **Download Firmware** button. Navigate to `Program Files\National Instruments\NI-IndCom for EtherCAT` and select the file with a `.foe` extension (such as `NI 9144 rev2.foe`) or a custom FPGA project with a `.lvbitx` extension, as shown in Figure 15.

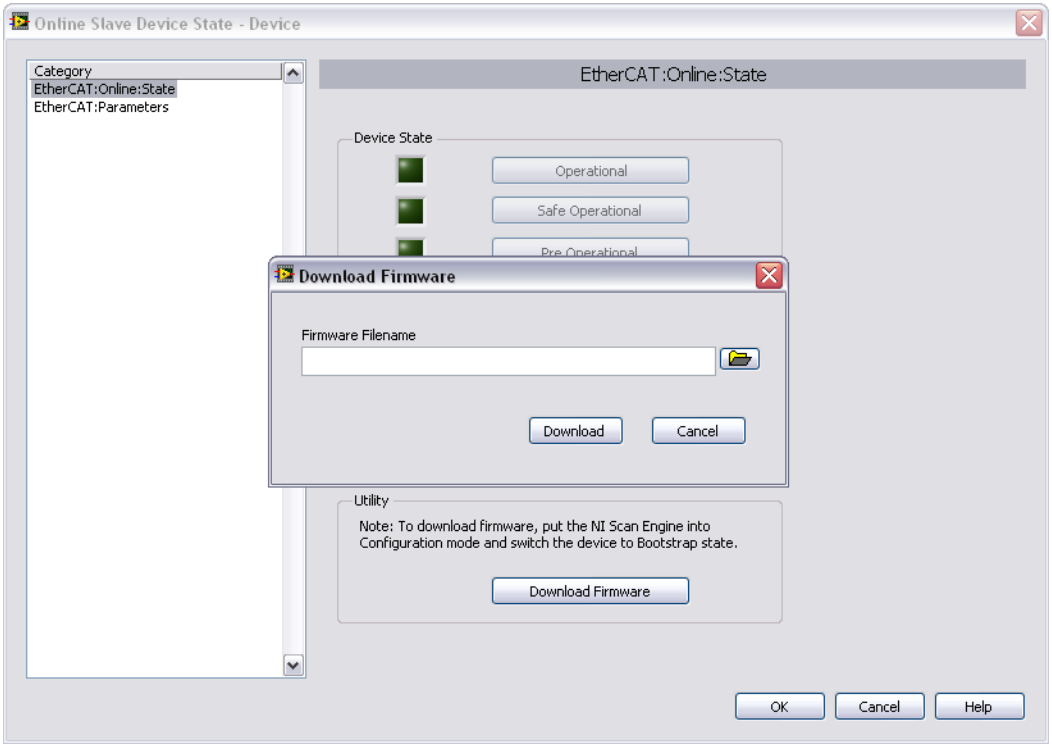


Figure 15. Download Firmware

Do *not* disconnect the device or interrupt firmware while it is downloading.

Using the NI 9144 with an EtherCAT Third-Party Master

All of the functionality of the NI C Series modules is available to third-party masters using vendor extensions to the object dictionary. The NI 9144 is a modular device, meaning each module plugged into the backplane has its own object dictionary, and each module configuration is done through this dictionary. If your master software supports AoE services (ADS over EtherCAT), you can address the module directly. If your master software does not support AoE services, you can still configure your module using NI vendor extensions and CoE (CAN over EtherCAT).

Using AoE/SDO

The AoE protocol allows you to specify the destination port or address of the SDO request. An address of 0 indicates the NI 9144 device, while addresses one through eight route the SDO request to the object dictionary of the module in the addressed slot. If no module is inserted in the addressed slot, the request fails. SDOInfo and SDO requests work with module object dictionaries over AoE in a manner similar to the NI 9144 main object dictionary.

Depending on the master software interface, you may be required to add 1,000 to the slot number to create a valid AoE address.

For more information, refer to your C Series module documentation.

Using CoE/SDO

The CoE protocol does not have a destination port or address, so the NI 9144 provides an object dictionary entry that allows addressing support. Prior to sending an SDO or SDOInfo request, your application can write a slot number of one through eight to the object dictionary index 0x5FFF subindex 0. Once this address is written, all future SDO transactions are sent to the object dictionary of the module in the addressed slot. If no module is inserted in the addressed slot, the request fails.

After the module-specific SDOInfo and SDO requests are complete, the application writes 0 to the module's object dictionary index 0x5FFF subindex 0 to return control to the NI 9144 main object dictionary.

For a list of all chassis and module object dictionary entries, refer to the *Appendix* of this user guide.

Specifications

The following specifications are typical for the –40 to 70 °C operating temperature range unless otherwise noted. For more information, refer to the specific module specifications.

Network

Network interface .....100BaseTX Ethernet

Compatibility .....EtherCAT

Communication rates .....100 Mbps

Maximum cabling distance.....100 m/segment

MTBF

MTBF .....458,557 hours at 25 °C, 77 °F; Bellcore Issue 6

Note Contact NI for Bellcore MTBF specifications at other temperatures or for MIL-HDBK-217F specifications. Go to `ni.com/certification` and search by model number or product line for more information about MTBF and other product certifications.

Power Requirements

Caution You must use a National Electric Code (NEC) UL Listed Class 2 power supply with the NI 9144 chassis.

Recommended power supply.....48 W, 24 VDC

Power consumption .....20 W maximum

Chassis input range.....9 to 30 V

Physical Characteristics

If you need to clean the controller, wipe it with a dry towel.

Screw-terminal wiring..... 0.5 to 2.5 mm^2 (24 to 12 AWG) copper conductor wire with 10 mm (0.39 in.) of insulation stripped from the end

Torque for screw terminals ..... 0.5 to 0.6 N · m (4.4 to 5.3 lb · in.)

Weight..... 906 g (32.7 oz)

Safety Voltages

Connect only voltages that are within these limits.

V terminal to C terminal ..... 30 V max, Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Caution Do not connect the system to signals or use for measurements within Measurement Categories II, III, or IV.

Hazardous Locations

U.S. (UL)..... Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nA IIC T4

Canada (C-UL)..... Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, Ex nA IIC T4

Europe (DEMKO)..... Ex nA IIC T4

Environmental

The NI 9144 chassis is intended for indoor use only, but it may be used outdoors if mounted in a suitably rated enclosure.

Operating temperature
(IEC 60068-2-1, IEC 60068-2-2) .....–40 to 70 °C

Note To meet this operating temperature range, follow the guidelines in the installation instructions for your EtherCAT system.

Storage temperature
(IEC 60068-2-1, IEC 60068-2-2) .....–40 to 85 °C

Ingress protection .....IP 40

Operating humidity (IEC 60068-2-56) ....10 to 90% RH, noncondensing

Storage humidity (IEC 60068-2-56).....5 to 95% RH, noncondensing

Maximum altitude.....2,000 m

Pollution Degree (IEC 60664).....2

Shock and Vibration

To meet these specifications, you must panel mount the EtherCAT system and affix ferrules to the ends of the power terminal wires.

Operating shock (IEC 60068-2-27).....30 g, 11 ms half sine,
50 g, 3 ms half sine,
18 shocks at 6 orientations

Operating vibration,
random (IEC 60068-2-64) .....5 g_{rms}, 10 to 500 Hz

Operating vibration,
sinusoidal (IEC 60068-2-6) .....5 g, 10 to 500 Hz

Table 2 shows the standard Ethernet cable wiring connections.

Table 2. Ethernet Cable Wiring Connections

Pin	Connector 1	Connector 2
1	white/orange	white/orange
2	orange	orange
3	white/green	white/green
4	blue	blue
5	white/blue	white/blue
6	green	green
7	white/brown	white/brown
8	brown	brown

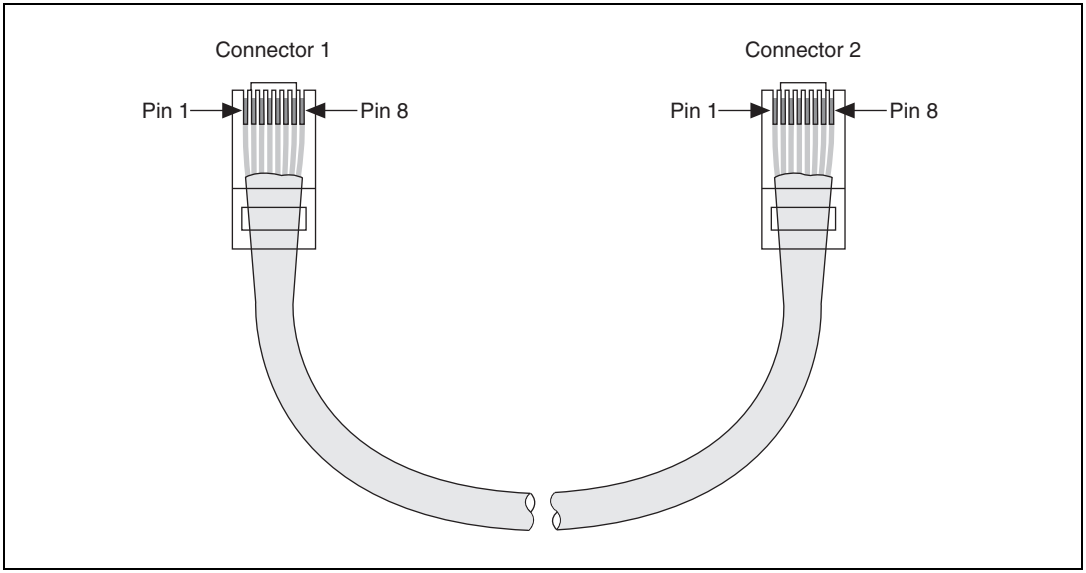


Figure 16. Ethernet Connector Pinout

Safety

This product meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Caution When operating this product, use shielded cables and accessories.

Note For EMC declarations and certifications, refer to the *Online Product Certification* section.

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

To obtain product certifications and the Declaration of Conformity (DoC) for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at `ni.com/environment`. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of the product life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers, National Instruments WEEE initiatives, and compliance with WEEE Directive 2002/96/EC on Waste and Electronic Equipment, visit `ni.com/environment/weee`.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

Appendix

Refer to the *Supported C Series Modules* section for a list of supported C Series modules.

Note Refer to the *NI 951x C Series Modules Object Dictionary* available from `ni.com/manuals` for NI 951*x* C Series drive interface module object dictionary entries.

Vendor Extensions to the Object Dictionary

Most object dictionary entries are defined by the relevant EtherCAT and CANOpen specification for modular slave devices. Both the NI 9144 device and the C Series modules have vendor extensions to the standard. These extensions are described here.

Note Most object dictionary entries are set to usable defaults during the NI 9144's transition from INIT to PRE-OP. NI recommends writing down the object dictionary default values, in case you need to revert to them, before you begin to overwrite them with new values prior to the transition to SAFE-OP.

Note The following lists the most common C Series module vendor extensions. Each module has its own extensions which may vary from the information listed here, and any given object dictionary index may have a different meaning depending on which module is inserted. For more information, refer to your C Series module documentation.

Table 3 lists common module vendor extensions.

Table 3. Module Vendor Extensions

Vendor Extension	Index	Sub	Type	R/W	Description
NI 9144	0x3001	0	ARR:U32	—	Timing overrides: provides additional control over the timing of the NI 9144.
	—	1	—	R/W	Minimum free-run cycle time in nanoseconds. Set to 0 to operate at the minimum cycle. Set to 1,000,000 for a 1 mS cycle (1 kHz).
	—	2	—	R/W	Disables multiple scans. Setting the field to 1 disables multiple-scan ability. Even when a module has enough time during the cycle to acquire more than one set of data, only one acquisition occurs. This is useful when analyzing the module acquisition timing.
	0x5FFF	0	U32	R/W	Slot address override. To address CoE requests to a given module's object dictionary, enter the module's slot number here. Write a 0 here to cancel the slot address override.

Table 3. Module Vendor Extensions (Continued)

Vendor Extension	Index	Sub	Type	R/W	Description
C Series Module	0x2000	0	U32	R	NI C Series Vendor ID (for NI C Series modules, equals 0x1093)
	0x2001	0..N	ARR:	R/W	• Scan or command list • Channel direction control • Mode selection
	0x2002	0	U32	R/W	• Error status • Unipolar/bipolar control • Module configuration command • Module conversion rate control
	0x2003	0	U32	R/W	Error acknowledgement (or status)
	0x2005	0	U8	R/W	• Refresh period • Conversion format
	0x2100	0..N	ARR:	R	Calibration data
	0x3002	0	U32	R	Number of scans. This index reports the number of conversions the module makes during the cycle. If disable multiple scans is selected, the number of scans is always 1.
	0x4000 … 0x47FF	—	—	R/W	Safe data values that mirror the PDO data in 0x6000…0x67FF.
	0x4800 … 0x4FFF	—	—	R/W	Safe control values that mirror the SDO data in 0x2000…0x27FF.

Supported C Series Modules

This section features configurable options for the following supported C Series modules:

- *NI 9201/9221*
- *NI 9203*
- *NI 9205/9206*
- *NI 9207*
- *NI 9208*
- *NI 9211*
- *NI 9213*
- *NI 9214*
- *NI 9215*
- *NI 9217*
- *NI 9219*
- *NI 9225*
- *NI 9227*
- *NI 9229/9239*
- *NI 9233*
- *NI 9234*
- *NI 9235*
- *NI 9236*
- *NI 9237*
- *NI 9263*
- *NI 9264*
- *NI 9265*
- *NI 9269*
- *NI 9401*
- *NI 9402*
- *NI 9403*
- *NI 9476*
- *NI 9478*
- *NI 951x*

Refer to the *C Series Modules with No Configurable Options* section for all other supported C Series modules.

NI 9201/9221

The vendor configuration extensions for the NI 9201/9221 are listed in Table 4.

Table 4. NI 9201/9221 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 9
	1		R	Channels to Convert = <1..8>, default = 8
	2..9		R/W	Channel Code
0x2002	0	U32	R/W	Fast Convert = 0/1, default = 1 (fast)
0x2100	0	ARR:U32	—	Calibration = 32
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	…		—	—
	15		R	Ch7 Offset
	16		R	Ch7 Gain
	17		R	External Calibration, Ch0 Offset
	…		—	—

NI 9201/9221 Scan List

The scan list channel codes consist of two bit fields in a 32-bit entry.

Table 5. NI 9201/9221 Scan List Format

Bits	Field
31..24	= 0
23..16	Data Offset[*t*]
15..8	= 0
7..0	Convert Flag[*t*+2]

Bits <23..16> describe the data offset to store a conversion at time *t*, and bits <7..0> describe the conversion control code that takes effect two conversions in the future, at time *t*+2. On the NI 9201/9221, this conversion code is a bit flag where bit 0 represents a conversion on channel 0, through bit 7 for channel 7.

So, for example, the scan list entry **0x00010008** indicates this scan stores at address 1, and the conversion two in the future is channel 3 (bit 3 set = 8).

Table 6 contains the default scan list.

Table 6. NI 9201/9221 Default Scan List

Index	Sub	Type	Value
0x2001	0	ARR:U32	9
	1		8
	2		0x00000004
	3		0x00010008
	4		0x00020010
	5		0x00030020
	6		0x00040040
	7		0x00050080
	8		0x00060001
	9		0x00070002

NI 9201/9221 Calibration Data

The NI 9201/9221 modules have eight channels with a nominal range of ±10.53 V and ±62.5 V, respectively. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 7. NI 9221/9201 Calibration Coefficients

Coefficient	Representation	Units
LSB Weight	Unsigned	nV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{corrected}(V_{raw}) = V_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{nV}{bits}\right) \times 10^{-9}\left(\frac{V}{nV}\right) \right\} - \left\{ Offset(nV) \times 10^{-9}\left(\frac{V}{nV}\right) \right\}$$

NI 9203

The vendor configuration extensions for the NI 9203 are listed in Table 8.

Table 8. NI 9203 Vendor Configuration Extensions

Index	Sub	Type	R/W	Value
0x2001	0	ARR:U32	—	Scan List = 9
	1		R	Channels to Convert = <1..8>, default = 8
	2..9		R/W	Channel Code
0x2002	0	U32	R/W	Unipolar Channel Mask
0x2100	0	ARR:U32	—	Calibration = 36
	1		R	Bipolar Offset
	2		R	Ch0 Bipolar Gain
	3		R	Ch1 Gain
	...		—	—
	9		R	Ch7 Gain
	10		R	Unipolar Offset
	11		R	Ch0 Unipolar Gain
	...		—	—
	19	R	R	External Calibration, Bipolar Gain
	...		—	—

NI 9203 Scan List

The scan list channel codes consist of three bit fields in a 32-bit entry.

Table 9. NI 9203 Scan List Format

Bits	Field
31..24	= 0
23..16	Data Offset[*t*]
15..4	= 0
3	Bipolar = 0, Unipoloar = 1
2..0	Channel Code[*t*+2]

Bits <23..16> describe the data offset to store a conversion at time *t*, and bits <3..0> describe the conversion control code that will take effect two conversions in the future, at time *t+2*. On the NI 9203, bit 3 determines

whether the result is bipolar (signed) or unipolar (unsigned), and bits <2..0> are the channel number reversed.

Table 10. NI 9203 Channels/Reversed Bits

Channel	Reversed Bits
0 = 0b000	0b000 = 0
1 = 0b001	0b100 = 4
2 = 0b010	0b010 = 2
3 = 0b011	0b110 = 6
4 = 0b100	0b001 = 1
5 = 0b101	0b101 = 5
6 = 0b110	0b011 = 3
7 = 0b111	0b111 = 7

For example, the scan list entry **0x00010006** indicates that this scan gets stored at address 1, and the conversion two is a bipolar channel 3 (3 reversed = 6).

Table 11 contains the default scan list.

Table 11. NI 9203 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	9
	1		8
	2		0x00000002
	3		0x00010006
	4		0x00020001
	5		0x00030005
	6		0x00040003
	7		0x00050007
	8		0x00060000
	9		0x00070004

NI 9203 Calibration Data

The NI 9203 has eight channels each with two modes. Each channel can have a nominal unipolar input range of 0–20 mA or bipolar ±20 mA. Each channel has an associated LSB weight, which is the number of amps per bit, and an offset, which is the number of amps per bit measured when the inputs are open.

Note LSB weight is referred to as Gain in the object dictionary.

The difference in offset from channel to channel is negligible.

The calibration data gives one offset and eight gains for each mode, a total of 2 offsets and 16 gains in total. All channels in a given mode use the same offset. The host can then take these constants and adjust the raw data into calibrated data.

The calibration data is stored in a U32 array, though each offset should be interpreted as a signed value.

Table 12. NI 9203 Calibration Coefficients

Coefficient	Representation	Units
LSB Weight	Unsigned	pA/LSB
Offset	Signed	pA

Use the calibration coefficients with the following equation to generate corrected data:

$$\underbrace{I_{corrected}(I_{raw})}_{\text{pA}} = \underbrace{\lfloor I_{raw} - I_{expected\ 0mA} \rfloor}_{\text{bits}} \times \underbrace{LSB_{weight}}_{\text{pA/bit}} - \underbrace{I_{offset}}_{\text{pA}}$$

Table 13. NI 9203 Calibration Equation Information

Term	Units	Definition
$I_{corrected}$	pA	Calibrated current
I_{raw}	bits	The raw code from the NI 9203
$I_{expected0mA}$	bits	Expected code at 0 mA. 0 bits for 0–20 mA range. 32768 bits for ±20 mA range
LSB_{weight}	pA/bit	Number of pA in one bit
I_{offset}	pA	Offset at 0 mA

NI 9205/9206

The vendor configuration extensions for the NI 9205/9206 are listed in Table 14.

Table 14. NI 9205/9206 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 33
	1		R	Channels to Convert = <1..32>, default = 32
	2..33		R/W	Channel Code
0x2100	0	ARR:U32	—	Calibration = 24
	1		R	Coeff 3
	2		R	Coeff 2
	3		R	Coeff 1
	4		R	Coeff 0
	5		R	10 V offset
	6		R	10 V gain
	7		R	5 V offset
	...		—	—
	13		R	User calibration, Coeff 3
	...		—	—

NI 9205/9206 Scan List

The scan list channel codes consist of eight bit fields in a 32-bit entry.

Table 15. Scan List Format

Bits	Field
31..24	= 0
23..16	Data Offset[*t*]
15..0	Conversion Code[*t*+2}

Bits <23..16> describe the data offset to store a conversion at time *t*, and bits <15..0> describe a complex conversion control code that takes effect two conversions in the future, at time *t+2*. On the NI 9205/9206, this conversion code is listed in Table 16.

Table 16. NI 9205/9206 Conversion Code

Bits	Field
15..13	001 = Read AI
12..11	Bank: 01 = Channels <0..15> 10 = Channels <16..31>
10..8	Channel LSB = <0..7>
7..6	00 = Cal Pos Ref5V
5..4	00 = NRSE 11 = Cal Neg AI GND RSE or DIFF
3..2	Mode: 10 = Single–End A (Ch. <0..7>, <16..23>) 11 = Single–End B (Ch. <8..15>, <24..31>)
1..0	00 = ±10 V 01 = ±5 V 10 = ±1 V 11 = ±200 mV

Table 17 contains the default scan list.

Table 17. NI 9205/9206 Scan List Format

Index	Sub	Type	Value	Sub	Value
0x2001	0	ARR:U32	33	—	—
	1		32	—	—
	2		0x00002A38	18	0x00103238
	3		0x00012B38	19	0x00113338
	4		0x00022C38	20	0x00123438
	5		0x00032D38	21	0x00133538
	6		0x00042E38	22	0x00143638
	7		0x00052F38	23	0x00153738
	8		0x0006283C	24	0x0016303C
	9		0x0007293C	25	0x0017313C
	10		0x00082A3C	26	0x0018323C
	11		0x00092B3C	27	0x0019333C
	12		0x000A2C3C	28	0x001A343C
	13		0x000B2D3C	29	0x001B353C
	14		0x000C2E3C	30	0x001C363C
	15		0x000D2F3C	31	0x001D373C
	16		0x000E3038	32	0x001E2838
	17		0x000F3138	33	0x001F2938

NI 9205/9206 Calibration Data

The NI 9205 uses a quadratic formula for conversion from 16-bit raw data to calibrated data.

The NI 9205 EEPROM provides overall polynominal values a3–a0 along with gain and offset values for each voltage range, to be applied when converting 16-bit raw data to calibrated data.

1. Convert the 32-bit hex values to 64-bit floating point format for use in the calibration formula.
2. Select the 32-bit gain value for a particular range.
3. Select the 32-bit offset value (to be interpreted as a signed int) for a particular range.

4. Use the above final coefficients and complete the following steps in the quadratic equation to convert raw 16-bit data into scaled volts:
   a. a0 = (f64(a0) × rangeGain) + rangeOffset
   b. a1 = f64(a1) × rangeGain
   c. a2 = f64(a2) × rangeGain
   d. a3 = f64(a3) × rangeGain
5. Use the following formula with a3–a0 to obtain the scaled 16-bit value in volts.

   where x = signed un-scaled 16-bit data read from device:

   Scaled 16-bit signed data in volts = a3 × x3 + a2 × x2 + a1 × x + a0

It is also possible to decode the raw data using only the offset and gain values. For more information, refer to the *NI 9201/9221* section of this guide.

NI 9207

The vendor configuration extensions for the NI 9207 are listed in Table 18.

Table 18. NI 9207 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 17
	1		R	Channels to Convert = <1..16>, default = 16
	2..17		R/W	Channel Code
0x2002	0	U32	R/W	Conversion Speed Control = 0 or 1, default = 1

NI 9207 Conversion Speed Control

The NI 9207 converts at two pre-defined rates, as controlled by the speed control field.

Note The conversion rate assumes that 16 channels are in the scan list.

Table 19. NI 9207 Conversion Speed Control

Speed Control	Meaning	Conversion Rate
0	High-Accuracy	62.5 ms/channel (1 s total)
1	High-Speed	1.92 ms/channel (30.72 ms total)

NI 9207 Scan List

The scan list is a simple list of channels to convert, in order. The NI 9207 has 16 total channels that can be measured.

Table 20. NI 9207 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	17
	1		16
	2		0
	3		1
	...		
	17		15

NI 9207 Calibration Data

Calibration data is set up by driver during initialization, and the calibration conversion is performed on the module ADC itself. Thus, you do not need to use the calibration tables.

NI 9208

The vendor configuration extensions for the NI 9208 are listed in Table 21.

Table 21. NI 9208 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	0	ARR:U32	—	Scan List = 17
	1		R	Channels to Convert = <1..16>, default = 16
	2..17		R/W	Channel Code
0x2002	0	U32	R/W	Conversion Speed Control = 0 or 1, default = 1

NI 9208 Conversion Speed Control

The NI 9208 converts at two pre-defined rates, as controlled by the speed control field.

Note The conversion rate assumes that 16 channels are in the scan list.

Table 22. NI 9208 Conversion Speed Control

Speed Control	Meaning	Conversion Rate
0	High-Accuracy	62.5 ms/channel (1 s total)
1	High-Speed	1.92 ms/channel (30.72 ms total)

NI 9208 Scan List

The scan list is a simple list of channels to convert, in order. The NI 9208 has sixteen total channels that can be measured.

Table 23. NI 9208 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	17
	1		16
	2		0
	3		1
	...		...
	17		15

NI 9208 Calibration Data

Calibration data is set up by driver during initialization, and the calibration conversion is performed on the module ADC itself. Thus, you do not need to use the calibration tables.

NI 9211

The vendor configuration extensions for the NI 9211 are listed in Table 24.

Table 24. NI 9211 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 7
	1		R	Channels to Convert = <1..6>, default = 6
	2..7		R/W	Channel Number

NI 9211 Scan List

The scan list is a simple list of channels to convert, in order. The NI 9211 has six channels total that can be measured:

- <0..3>: four input channels (always measured in a ±80 mV range)
- 4: one cold junction channel (always measured in a ±2.5 V range)
- 5: one auto zero channel (always measured in a ±80 mV range)

Table 25 contains the default scan list.

Table 25. NI 9211 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	7
	1		6
	2		0
	3		1
	...		...
	7		5

NI 9211 Calibration Data

Calibration data is set up by the driver during initialization, and the calibration conversion is performed on the module ADC itself.

NI 9213

The vendor configuration extensions for the NI 9213 are listed in Table 26.

Table 26. NI 9213 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	0	ARR:U32	—	Scan List = 16
	1		R	Channels to Convert = <1..18>, default = 18
	2..19		R/W	Channel Code
0x2100	0	U32	R/W	Channel Speed Control = 2 or 15, default = 2
0x2003		U32	R	Common Mode Range Error Detection Status (also as 8-bit PDO)

NI 9213 Conversion Speed Control

The NI 9213 can convert at two pre-defined rates, as controlled by the speed control field.

Note The conversion rate assumes that 18 channels are in the scan list.

Table 27. NI 9213 Conversion Speed Control

Speed Control	Meaning	Conversion Rate
2 (0x02)	High-Accuracy	55 ms/channel (.99 s total)
15 (0x0F)	High-Speed	740 µs/channel (12.32 ms total)

NI 9213 Common Mode Error/Status

The error/status field is defined as listed in Table 28.

Table 28. NI 9213 Conversion Code

Bits	Field
31..8	Reserved
7	OT Error: 1 = Open thermocouple detected on the last channel acquired.
6	CMV Error: 1 = Common mode voltage error detected on the last channel acquired.
5	GO Status: status of the gain override enable bit

Table 28. NI 9213 Conversion Code (Continued)

Bits	Field
4	Reserved
3..0	Currently configured ADC data rate

NI 9213 Scan List

The scan list is a simple list of channels to convert, in order. The NI 9213 has eighteen total channels that can be measured:

- <0..15>: sixteen thermocouple channels (always measured in a ±78 mV range)
- 12: one cold junction channel (always measured in a ±2.5 V range)
- 17: one auto zero channel (always measured in a ±78 mV range)

Table 29 contains the default scan list.

Table 29. NI 9213 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	19
	1		18
	2		0
	3		1
	...		...
	18		16
	19		17

NI 9213 Calibration Data

Calibration data is set up by the driver during initialization, and the calibration conversion is performed on the module ADC itself, so the third-party user does not need to worry about the calibration tables.

NI 9214

The vendor configuration extensions for the NI 9214 are listed in Table 30.

Table 30. NI 9214 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 21
	1		R	Channels to Convert = 1..20, default = 20
	2..21		R/W	Channel Code
0x2002	0	U32	R/W	Conversion Speed Control/Open Thermocouple Detection
0x2003	0	U32	R	Common Mode Range Error Detection Status (also as 8-bit PDO)

Conversion Speed Control/Open Thermocouple Detection (0x2002)

The NI 9214 can convert at two pre-defined rates, as controlled by the speed control field. Note that the conversion rate assumes that 20 channels are in the scan list. The NI 9214 can also enable/disable open thermocouple detection.

Table 31. NI 9214 Conversion Speed Control/Open Thermocouple Detection

Bits	Field
31:5	Reserved
4	Open Thermocouple Detection: 0x10: Enable 0x00: Disable
3:0	Conversion Speed Control: 0x02: High-Accuracy, 52 ms/channel (1.04 s total) 0x0F: High-Speed, 735 µs/channel (14.7 ms total)

Common Mode Error/Status (0x2003)

The error/status field is defined as shown in Table 32.

Table 32. NI 9214 Error/Status Field

Bits	Field
31:8	Reserved
7	OT Error: 1 = Open thermocouple was detected on the last channel that was acquired.

Table 32. NI 9214 Error/Status Field (Continued)

Bits	Field
6	CMV Error: 1 = Common mode voltage error was detected on the last channel that was acquired
5	GO Status: Status of the gain override enable bit
4	Reserved
3:0	Currently configured ADC data rate

Scan List

The scan list is a simple list of channels to convert, in order. The NI 9214 has 20 total channels that can be measured:

- 0..15: 16 thermocouple channels (always measured in a ±78 mV range)
- 16: One auto zero channel (always measured in a ±78 mV range)
- 17: Cold junction channel 0 (always measured in a ±2.5 V range)
- 18: Cold junction channel 1 (always measured in a ±2.5 V range)
- 19: Cold junction channel 2 (always measured in a ±2.5 V range)

The default scan list is defined as shown in Table 33.

Table 33. NI 9214 Vendor Configuration Extensions

Index	Sub	Type	Value
0x2001	0	ARR:U32	21
	1		20
	2		0
	3		1
	…		—
	20		18
	21		19

Calibration Data

Calibration data is set up by the driver during initialization, and the calibration conversion is performed on the module ADC itself, so the third-party user does not need to worry about the calibration tables.

NI 9215

The vendor configuration extensions for the NI 9215 are listed in Table 34.

Table 34. NI 9215 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	...		—	—
	7		R	Ch3 Offset
	8		R	Ch3 Gain
	9		R	External Calibration, Ch0 Offset
	...		—	—

NI 9215 Calibration Data

The NI 9215 has four channels with a nominal range of ±10.4 V. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The NI 9215 EEPROM stores these two constants for each channel. The host can then take these constants and adjust the raw data into calibrated data.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 35. NI 9215 Calibration Coefficients

Coefficient	Representation	Units
LSB Weight	Unsigned	nV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{corrected}(V_{raw}) = V_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{nV}{bits}\right) \times 10^{-9}\left(\frac{V}{nV}\right) \right\} - Offset(nV) \times 10^{-9}\left(\frac{V}{nV}\right) \Bigg\}$$

NI 9217

The vendor configuration extensions for the NI 9217 are listed in Table 36.

Table 36. NI 9217 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Scan List = 5
	1		R	Channels to Convert = <1..4>, default = 4
	2..5		R/W	Channel Code
0x2002	0	U32	R/W	Conversion Speed Control = 2 or 31, default = 31
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9217 Conversion Speed Control

The NI 9217 converts at two pre-defined rates, as controlled by the speed control field.

Note The conversion rate assumes that 4 channels are in the scan list.

Table 37. NI 9217 Conversion Speed Control

Speed Control	Meaning	Conversion Rate
31 (0x1F)	High-Accuracy	200 ms/channel (800 ms total)
2 (0x02)	High-Speed	2.5 ms/channel (10 ms total)

NI 9217 Scan List

The scan list channel codes consist of three bit fields in a 32-bit entry.

Table 38. NI 9217 Conversion Code

Bits	Field
31..16	Reserved
15..8	Data Offset[t]
7..0	Convert Code [t=1]

Bits <15..8> describe the data offset to store a conversion at time *t*, and bits <7..0> describe the conversion control codes that take effect one conversion in the future, at time *t* +2. The conversion code is listed in Table 39.

Table 39. NI 9217 Conversion Code

Bits	Field
7..3	Conversion rate: 0b11111 = 31, High-Accuracy 0b00010 = 2, High-Speed
2..1	Channel number
0	Reserved

Note The conversion rate for every channel must match the value of the conversion speed control in 0x2002.

For example, the scan list entry 0x00000001FC indicates this scan stores at address 1, and the next conversion is channel 2 at high-accuracy.

Table 40 contains the default scan list.

Table 40. NI 9217 Scan List Format

Index	Sub	Type	Value
0x2001	0	ARR:U32	5
	1		4
	2		0x0000 | 0xF8 | 0x02
	3		0x0100 | 0xF8 | 0x04
	4		0x0200 | 0xF8 | 0x06
	5		0x0300 | 0xF8 | 0x00

NI 9217 Calibration Data

The NI 9217 has four RTD channels that can measure 100 Ω RTD in 3-wire and 4-wire mode. There is a 1 mA excitation current source per channel and the module range is –500 to 500 Ω. The resistance range specified in the manual is 0 to 400 Ω. This range is tested and covers the temperature range of –200 to 850 ºC for the standard platinum RTD. The channel does not read negative resistance.

Each channel has an associated LSB weight, which is the number of ohms per bit, and an offset, which is the number of ohms per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 41. NI 9217 Calibration Coefficients

Coefficient	Representation	Units
LSB Weight	Unsigned	pΩ/LSB
Offset	Signed	mW

Use the calibration coefficients with the following equation to generate correct data:

$$R_{corrected}(R_{raw}) = R_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{p\Omega}{bits}\right) \times 10^{-12}\left(\frac{\Omega}{p\Omega}\right) \right\} - Offset(\mu\Omega) \times 10^{-6}\left(\frac{\Omega}{\mu\Omega}\right)$$

where $R_{raw}(bits)$ = data returned by the NI 9217 in bits

$R_{corrected}$ = calibrated resistance reading

NI 9219

The vendor configuration extensions for the NI 9219 are listed in Table 42.

Table 42. NI 9219 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	ARR:U32	—	Command List = 33
	1		R	Command Count = <1..32>, default = 32
	2..33		R/W	Configuration Command
0x2002	1	ARR:U32	R	Error Status
0x2005	0	U32	R/W	ADC Format
0x2100	0	ARR:U32		Calibration = 168
	1		R	Ch0 60 V Offset
	2		R	Ch0 60 V Offset
	3		R	Ch0 15 V Offset
	...		—	—
	42		R	Ch0 Full Bridge 7.8m V–V Gain
	43		R	Ch1 60 V Offset
	...		—	—
0x2101	0	ARR:U32		External Calibration = 168
	1	—	R	Ch0 60 V Offset
...	...	...	...	...

NI 9219 ADC Format

The NI 9219 converts at different rates, and can specify different data formatting styles. This is determined by both the ADC Format field and corresponding fields in the setup commands. The format of the ADC Format field is shown in Table 43.

Table 43. NI 9219 ADC Format

Bits	Field
31..24	Reserved
23..16	Conversion speed in multiples of 10 mS
15..8	Reserved
7..0	AI Data Formatting

Standard values for ADC format are:

- 0x0001000F, High-Speed
- 0x000B000F, Best 60 Hz rejection
- 0x000D000F, Best 50 Hz rejection
- 0x0032000F, High-Resolution

NI 9219 Error Status

Caution Configuring all the channels in full-bridge mode shorts the channels and results in the firmware setting all the bits in the lower nibble.

When a channel over-current condition occurs on any of the channels of the NI 9219 (such as, configure channels in 4-wire resistance mode and do not connect a resistor to the channel), the firmware sets a bit in the lower nibble indicating the presence of this condition (LSB = ch0).

Errors are automatically internally acknowledged on the cycle after the error is reported.

NI 9219 Calibration Data

The NI 9219 has four channels which each have 21 different operating modes and ranges. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The operating modes and ranges, in the order they are defined in the calibration table for each channel, are listed in Table 44.

Table 44. NI 9219 Channel Calibration

Entry Number	Mode	Range
1	Voltage	±60 V
2		±15 V
3		±4 V
4		±1 V
5		±125 mV
6	Current	±25 mA
7	4-Wire Resistance	10 kΩ
8		1 kΩ

Table 44. NI 9219 Channel Calibration (Continued)

Entry Number	Mode	Range
9	2-Wire Resistance	10 kΩ
10		1 kΩ
11	Thermocouple	—
12	4-Wire RTD	Pt1000
13		Pt100
14	3-Wire RTD	Pt1000
15		Pt100
16	Quarter-Bridge	350 Ω
17		120 Ω
18	Half-Bridge	±500 mV/V
19	Reserved	—
20	Full-Bridge	±62.5 mV/V
21		±7.8 mV/V

The calibration data is stored in a U32 array, though each offset field should be interpreted as a signed value.

Table 45. NI 9219 Calibration Data

Coefficient	Representation
LSB Weight	Unsigned
Offset	Signed

The NI 9219 returns calibrated 24-bit (padded to 32-bits) AI data for all modes and ranges.

To convert raw data into engineering units use the following formula:

$$y = m \times x + b$$

where b = Offset based on range of the device: such as, –60 for ± 60 V Voltage Measurement Range

m = Gain (Full-Range/(2^{24})): such as, 120/(2^{24}) for ± 60 V Voltage Measurement Range

NI 9219 Configuration Commands

There are eight configuration commands for the NI 9219.
Eight configuration commands must be sent for each of the four channels. This is true even if you are only using a subset of the four channels. Each of the eight configuration commands is 1 Byte, each configuration command is followed by a data Byte, and then by a CRC value, which is 1 Byte. Hence, 3 Bytes × 8 commands × 4 channels = 96 command bytes (held in 32 entries in the object dictionary).

Data in the object dictionary is held in LSB format, so the value 0x12345678 is represented in memory as the series of bytes 0x78, 0x56, 0x34, 0x12. The command word format is shown in Table 46.

Table 46. NI 9219 Command Word Format

Bits	Field
31..24	Reserved
23..16	CRC
15..8	Configuration Data
7..0	Configuration Command

NI 9219 CRC Calculation

```
U8 crcShiftReg = 0;
   for ( x = 0 ; x < 8 ; ++x )
   {
      dataBool = ((0x80>>x) & configCommand) != 0;
      shiftBool = (0x01 & crcShiftReg) != 0;
      crcShiftReg /= 2;
      if (dataBool != shiftBool)
         crcShiftReg ^= 0x8C;
   }
   for ( x = 0 ; x < 8 ; ++x )
   {
     dataBool = ((0x80>>x) & configData) != 0;
      shiftBool = (0x01 & crcShiftReg) != 0;
      crcShiftReg /= 2;
      if (dataBool != shiftBool)
         crcShiftReg ^= 0x8C;

   }

   crcShiftReg = crcShiftReg << 1;

   return crcShiftReg;
```

NI 9219 Configuration Command

Whether you are using the channel or not, you must configure the Conversion Time, Mode, Range, and Calibration Gain/Offset values for each channel on the NI 9219.

Note You must first send calibration gain and offset values in MSB format. The Conversion Time value must be the same across all channels.

Table 47. NI 9219 Scan List Format

Bits	Field	Description
7..6	Channel Number, <0..3>	—
5	= 0	—
4..0	Configuration Type	Conversion Type values: Conversion Time 0x1F Mode & Range 0x01 Calibration Offset 2 (LSB) 0x06 Calibration Offset 1 0x05 Calibration Offset 0 (MSB) 0x04 Calibration Gain 2 (LSB) 0x0A Calibration Gain 1 0x09 Calibration Gain 0 (MSB) 0x08

NI 9219 Configuration Data

Table 48. NI 9219 Type Conversion Time

Configuration Value	Max Frequency	Conversion Time	Description
0x01	100 Hz/50 Hz (TC)	10 ms/20 ms (TC)	High Speed
0x08	9.09 Hz/8.33 Hz (TC)	110 ms/120 ms (TC)	Best 60 Hz Rejection
0x09	7.69 Hz/7.14 Hz (TC)	130 ms/140 ms (TC)	Best 50 Hz Rejection
0x0F	2 Hz/1.96 Hz (TC)	500 ms/510 ms (TC)	High Resolution

Note When any AI data channel is configured for Thermocouple, ADC conversion time increases by 10 ms for all channels. Refer to *Max Frequency* in Table 48 for various ACD timing configurations. The TC mode/range configuration code is 0x0A.

Table 49. NI 9219 Mode and Range Type

Configuration Value	Mode	Range
0x00	Voltage	60 V
0x01		15 V
0x02		3.75 V
0x03		1 V
0x04		.125 V
0x05	Current	25 mA
0x06	Resistance	10K 4w
0x07		1K 4w
0x08		10K 2w
0x09		1K 2w
0x0A	TC	TC
0x0B	RTD	Pt1000 4w
0x0C		Pt100 4w
0x0D		Pt1000 3w
0x0E		Pt100 3w
0x0F	Quarter-Bridge	350 Ω
0x10		120 Ω
0x11	Half-Bridge	1 V/V
0x13	Full-Bridge CJC	62.5 mV/V
0x14		7.8 mV/V
0x17		CJC range

NI 9219 Example Command Words Sequence

Note The order in which you send the commands is important.

Configuration 1: all Channels <ai0..ai3> for Voltage AI, ±15 Volt Range, High Speed Mode (100 Hz Max Sample Rate).

Table 50. NI 9219 Configuration 1: Command Bytes

Command Byte Value	Description
0x01	ADC Mode Configuration Byte – Channel 0
0x01	Data Byte
0x46	CRC value
0x1F	Mode/Range Configuration – Channel 0
0x01	Data Byte
0xC6	CRC value
0x04	Calibration Offset MSB – Channel 0
0x7F	Data Byte
0x54	CRC value
0x05	Calibration Offset Byte 2 – Channel 0
0xFF	Data Byte
0xB6	CRC value
0x06	Calibration Offset LSB – Channel 0
0x85	Data Byte
0x56	CRC value
0x08	Calibration Gain MSB – Channel 0
0x6C	Data Byte
0x1E	CRC value
0x09	Calibration Gain Byte 2 – Channel 0
0xAA	Data Byte
0x4E	CRC value
0x0A	Calibration Gain LSB – Channel 0
0xC1	Data Byte
0x32	CRC value
0x41	ADC Mode Configuration Byte – Channel 1
0x01	Data Byte
0x64	CRC value
0x5F	Mode/Range Configuration – Channel 1
0x01	Data Byte
0xE4	CRC value

Table 50. NI 9219 Configuration 1: Command Bytes (Continued)

Command Byte Value	Description
0x44	Calibration Offset MSB – Channel 1
0x7F	Data Byte
0x76	CRC value
0x45	Calibration Offset Byte 2 – Channel 1
0xFF	Data Byte
0x94	CRC value
0x46	Calibration Offset LSB – Channel 1
0x86	Data Byte
0xE0	CRC value
0x48	Calibration Gain MSB – Channel 1
0x6C	Data Byte
0x3C	CRC value
0x49	Calibration Gain Byte 2 – Channel 1
0x76	Data Byte
0x50	CRC value
0x4A	Calibration Gain LSB – Channel 1
0x3C	Data Byte
0xF6	CRC value
0x81	ADC Mode Configuration Byte – Channel 2
0x01	Data Byte
0xCE	CRC value
0x9F	Mode/Range Configuration – Channel 2
0x01	Data Byte
0x4E	CRC value
0x84	Calibration Offset MSB – Channel 2
0x7F	Data Byte
0xDC	CRC value
0x85	Calibration Offset Byte 2 – Channel 2
0xFF	Data Byte
0x3E	CRC value
0x86	Calibration Offset LSB – Channel 2

Table 50. NI 9219 Configuration 1: Command Bytes (Continued)

Command Byte Value	Description
0xC8	Data Byte
0xC2	CRC value
0x88	Calibration Gain MSB – Channel 2
0x6C	Data Byte
0x96	CRC value
0x89	Calibration Gain Byte 2 – Channel 2
0xB0	Data Byte
0xF4	CRC value
0x8A	Calibration Gain LSB – Channel 2
0x90	Data Byte
0x5E	CRC value
0xC1	ADC Mode Configuration Byte – Channel 3
0x01	Data Byte
0xEC	CRC value
0xDF	Mode/Range Configuration – Channel 3
0x01	Data Byte
0x6C	CRC value
0xC4	Calibration Offset MSB – Channel 3
0x7F	Data Byte
0xFE	CRC value
0xC5	Calibration Offset Byte 2 – Channel 3
0xFF	Data Byte
0x1C	CRC value
0xC6	Calibration Offset LSB – Channel 3
0xD3	Data Byte
0xCA	CRC value
0xC8	Calibration Gain MSB – Channel 3
0x6C	Data Byte
0xB4	CRC value
0xC9	Calibration Gain Byte 2 – Channel 3
0xD8	Data Byte

Table 50. NI 9219 Configuration 1: Command Bytes (Continued)

Command Byte Value	Description
0x56	CRC value
0xCA	Calibration Gain LSB – Channel 3
0x65	Data Byte
0xA0	CRC value

NI 9225

The vendor configuration extensions for the NI 9225 are listed in Table 51.

Table 51. NI 9225 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0x0A
0x2100	0	ARR:U32	—	Calibration = 12
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	6		R	Ch2 Gain
	7		R	External Ch0 Offset
	...		—	—

As a DSA module, the NI 9225 does not synchronize to other modules and free-runs at its own fixed rate.

For more information, refer to the *NI 9233 Configure ADC* section of this user guide.

NI 9227

The vendor configuration extensions for the NI 9227 are listed in Table 52.

Table 52. NI 9227 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0x0A
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

As a DSA module, the NI 9227 does not synchronize to other modules and free-runs at its own fixed rate.

For more information, refer to the *NI 9233 Configure ADC* section of this user guide.

NI 9229/9239

The vendor configuration extensions for the NI 9229/9239 are listed in Table 53.

Table 53. NI 9229/9239 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0x06
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

As a DSA module, the NI 9229/9239 does not synchronize to other modules and free-runs at its own fixed rate.

For more information, refer to the *NI 9233 Configure ADC* section of this user guide.

Note The NI 9229/9239 does not have the Turbo Bit configuration byte.

NI 9229/9239 Calibration Data

The NI 9229/9239 have four channels with nominal ranges of ±10 V and ±60 V respectively. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 54. NI 9229/9239 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	pV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{corrected}(V_{raw}) = V_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{pV}{bits}\right) \times 10^{-12}\left(\frac{V}{pV}\right) \right\} - Offset(pV) \times 10^{-9}\left(\frac{V}{nV}\right)$$

NI 9233

As a DSA module, the NI 9233 does not synchronize to other modules and free-runs at its own fixed rate. The vendor configuration extensions for the NI 9233 are listed in Table 55.

Table 55. NI 9233 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0x0A
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9233 Configure ADC

The NI 9233 (and NI 9229/9239) converts at various rates, controlled by the field in the ADC conversion command.

Table 56. NI 9233 Scan List Format

Bits	Field	Description
7	Turbo Disable (NI 9233 only)	0 = The conversion rate is equal to the oversample clock rate/128. Set to 0 for conversion rates > 25 kS/s. 1 = The conversion rate is equal to the oversample clock rate/256. Set to 1 for conversion rates < 25 kS/s.
6..2	Clock Divisor	The clock source (internal or external) is divided by this value and used as the converters' oversample clock. Valid values are from 2 to 31, but the final divided clock must be between 512 kHz and 6.4 MHz. This means that only values from 2 to 25 are valid when using the 12.8 MHz internal clock source.
1..0	Clock Source = 2	0b00 = 0: The OCLK pin is used as the oversample clock source. 0b01 = 1: The 12.8 MHz internal clock is used as the clock source and this 12.8 MHz is driven onto the OCLK pin. 0b10 = 2: The internal clock is used but not driven onto OCLK pin. Currently, this is the required clock setting. 0b11 = 3: Reserved.

Table 57. NI 9233 Calibration Data

Data Rate	Turbo Disable	Clock Divisor	Clock Source	Configure ADC	Oversample Clock Rate
50.000 kS/s	0	00010	10	0x0A	6.40 MHz
25.000 kS/s	1	00010	10	0x8A	6.40 MHz
12.500 kS/s	1	00100	10	0x92	3.20 MHz
10.000 kS/s	1	00101	10	0x96	2.56 MHz
6.250 kS/s	1	01000	10	0xA2	1.60 MHz
5.000 kS/s	1	01010	10	0xAA	1.28 MHz
3.333 kS/s	1	01111	10	0xBE	853 kHz
3.125 kS/s	1	10000	10	0xC2	800 kHz
2.500 kS/s	1	10100	10	0xD2	640 kHz
2.000 kS/s	1	11001	10	0xE6	512 kHz

NI 9233 Calibration Data

The NI 9233 has four input channels with a fixed gain. The inputs are AC-coupled, so calibration is done with a sine wave rather than with DC signals. The specification derivations are based on calibration at 250 Hz, acquired at 25 kS/s. The AC response (flatness) changes with both input frequency and sample rate; therefore, calibrating at different signal frequencies or at different sample rates gives different results.

Each channel has an associated LSB weight, which is the number of volts per bit, and an offset.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 58. NI 9233 Scan List Format

Coefficient	Representation	Units	Default Value
LSB Weight	Unsigned	pV/LSB	0x0009D292 (643.73 nV/bit)
Offset	Signed	nV	0x00000000 (0 nV)

Use the calibration coefficients with the following equation to generate corrected data:

$$Calibrated_Data = Binary_Data \times LSB_Weight - Offset$$

NI 9234

The vendor configuration extensions for the NI 9234 are listed in Table 59.

Table 59. NI 9234 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure Module, default = 0x06
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch0 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

As a DSA module, the NI 9234 does not synchronize to other modules and free-runs at its own fixed rate.

NI 9234 Configure Module

The NI 9234 has a variety of configuration fields available. Configuration bits <15..8> control the channel mode, while bits <7..0> set the conversion rate.

Table 60. NI 9234 Scan List Format

Bits	Field	Description
15	Ch3 IEPE	IEPE Enable 3: When set, the corresponding channel's relays are switched to IEPE operation. IEPE operations switches the AC/DC relay to AC mode and enables the IEPE relay to send the current to the IEPE sensor.
14	Ch3 AC/~DC	AC/~DC 3: Controls the AC/DC relay when IEPE is not selected. If IEPE is enabled, then these bits have no meaning as AC mode is always selected with an IEPE operation.
13	Ch2 IEPE	IEPE Enable 2: When set, the corresponding channel's relays are switched to IEPE operation. IEPE operations switches the AC/DC relay to AC mode and enables the IEPE relay to send the current to the IEPE sensor.
12	Ch2 AC/~DC	AC/~DC 2: Controls the AC/DC relay when IEPE is not selected. If IEPE is enabled, then these bits have no meaning as AC mode is always selected with an IEPE operation.
11	Ch1 IEPE	IEPE Enable 1: When set, the corresponding channel's relays are switched to IEPE operation. IEPE operations switches the AC/DC relay to AC mode and enables the IEPE relay to send the current to the IEPE sensor.

Table 60. NI 9234 Scan List Format (Continued)

Bits	Field	Description
10	Ch1 AC/~DC	AC/~DC 1: Controls the AC/DC relay when IEPE is not selected. If IEPE is enabled, then these bits have no meaning as AC mode is always selected with an IEPE operation.
9	Ch0 IEPE	IEPE Enable 0: When set, the corresponding channel's relays are switched to IEPE operation. IEPE operations switches the AC/DC relay to AC mode and enables the IEPE relay to send the current to the IEPE sensor.
8	Ch0 AC/~DC	AC/~DC 0: Controls the AC/DC relay when IEPE is not selected. If IEPE is enabled, then these bits have no meaning as AC mode is always selected with an IEPE operation.
7	Reserved	—
6..2	Clock Divisor	Clock Divisor: The NI 9234 divides the clock source (internal or external) by this value and uses it as the converters' oversample clock. The data rate is equal to 1/256 times this oversample clock frequency. Valid values for Clock Divisor are from 1 to 31, and the final divided clock must be between 100 KHz and 12.8 MHz.
1..0	Clock Source	0b00 = 0: The OCLK pin is used as the oversample clock source. 0b01 = 1: The 12.8 MHz internal clock is used as the clock source and this 12.8 MHz is driven onto the OCLK pin. 0b10 = 2: The internal clock is used but not driven onto OCLK pin. Currently, this is the required clock setting. 0b11 = 3: Reserved.

NI 9234 Example Data Rates

The example data rates use a 12.8 MHz clock source.

Table 61. NI 9234 Example Data Rates

Data Rate	Clock Divisor	Clock Source	Rate Byte	Oversample Clock Rate
50.000 kS/s	00001	10	0x06	12.80 MHz
25.000 kS/s	00010	10	0x0A	6.40 MHz
16.667 kS/s	00011	10	0x0E	4.27 MHz
12.500 kS/s	00100	10	0x12	3.20 MHz
10.000 kS/s	00101	10	0x16	2.56 MHz
6.250 kS/s	01000	10	0x22	1.60 MHz
5.000 kS/s	01010	10	0x2A	1.28 MHz

NI 9234 Calibration Data

The NI 9234 has four channels with a nominal range of ± 5 V. Each channel has an associated AC or DC input mode; an optional IEPE excitation; an associated LSB weight, which is how many volts there are per bit; and an offset, which is the volts per bit measured with the inputs grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 62. NI 9234 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	pV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{corrected}(V_{raw}) = V_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{pV}{bits}\right) \times 10^{-12}\left(\frac{V}{pV}\right) \right\} - Offset(pV) \times 10^{-9}\left(\frac{V}{nV}\right)$$

NI 9235

The vendor configuration extensions for the NI 9235 are listed in Table 63.

Table 63. NI 9235 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0xCE00
0x2100	0	ARR:U32	—	Calibration = 48
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch0 Shunt
	4		R	Ch1 Offset
	...		—	—
	24		R	Ch7 Shunt
	25		R	External Ch0 Offset
	...		—	—

The NI 9235 is a DSA module and as such does not synchronize with other modules but free-runs at its own fixed rate.

Configure ADC

The NI 9235 (like the other DSA modules) can convert at various rates, controlled by the fields in the ADC conversion command.

Table 64. NI 9235 Scan List Format

Bits	Field	Description
15..10	Clock Divisor	The clock source (internal or external) is divided by one half of this value and used as the converter's oversample clock. Valid values are from 2 to 63, but the final divided clock must be between 502 kHz and 5.12 MHz. This means that only values from 5 to 51 (representing the divisors 2.5 to 25.5) are valid when using the 12.8 MHz internal clock source.

Table 64. NI 9235 Scan List Format (Continued)

Bits	Field	Description
9..8	Clock Source	0b00 = 0: The OCLK pin is used as the oversample clock source. 0b01 = 1: The 12.8 MHz internal clock is used as the clock source and this 12.8 MHz is driven onto the OCLK pin. 0b10 = 2: The internal clock is used but not driven onto OCLK pin. Currently, this is the required clock setting. 0b11 = 3: Reserved.
7..0	Shunt Cal Enable <ch7..ch0>	Controls the shunt calibration switch for each of the eight channels. A logic 1 in any bit closes the switch for the respective channel, while a logic 0 opens the switch. Refer to Table 65 for example data rates using a 12.8 MHz clock source (and using 0x00 in the shunt cal enable bits).

Table 65. NI 9235 Calibration Data

Data Rate	Clock Divisor	Clock Source	Configure ADC	Oversample Clock Rate
10.000 kS/s	000101	10	0x1600	5.12 MHz
8.333 kS/s	000110	10	0x1A00	4.27 MHz
7.143 kS/s	000111	10	0x1E00	3.66 MHz
2.500 kS/s	010100	10	0x5200	1.28 MHz
1.613 kS/s	011111	10	0x7E00	825.8 kHz
1.250 kS/s	101000	10	0xA200	640.0 kHz
0.980 kS/s	110011	10	0xCE00	502.0 kHz

NI 9235 Calibration Data

The NI 9235 has eight input channels for measuring strain. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

There is also a shunt measurement value which is not used during normal operation. The calibration data is stored in an U32 array, though each Offset field (subindex 1, 4, 7, etc.) should be interpreted as a signed value.

Table 66. NI 9235 Calibration Coefficients

Coefficient	Representation
LSB Weight	Unsigned

Table 66. NI 9235 Calibration Coefficients (Continued)

Coefficient	Representation
Offset	Signed
Shunt	Signed

The calibration coefficients are used with the following equation to generate corrected data:

$$Nominal\left(\frac{V}{V}\right) = Binary_{Data} \times LSB_{Weight} \times 1e-13 - Offset \times 1e-7$$

The resultant calibrated reading is a ratio between the bridge input voltage and the excitation voltage, termed V_r. However, typical quarter bridge measurements are denominated in strain, which require not only conversion in the strain equation, but also the acquisition and use of an unstrained measurement.

Due to initial tolerances in all of the bridge elements (but primarily of the gage itself), the module reading is nonzero even when the gage is in an unstrained state. If handled correctly, this is not a source of inaccuracy, because strain measurement is inherently a delta measurement. Accordingly, a fundamental element of strain measurement involves the capture of this unstrained measurement, which is analogous to the cold junction measurement of a thermocouple measurement system. The strain equation is:

$$strain(e) = \frac{-4(V_{r-st} - V_{r-unst})}{GF \cdot [(1+2) \cdot (V_{r-st} - V_{r-unst})]}$$

where V_{r_st} ad V_{r_unst} are the strained and unstrained readings, respectively from the module.

NI 9236

The vendor configuration extensions for the NI 9236 are listed in Table 67.

Table 67. NI 9236 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure ADC, default = 0xCE00
0x2100	0	ARR:U32	...	Calibration = 48
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch0 Shunt
	4		R	Ch1 Offset
	...		—	—
	24		R	Ch7 Shunt
	25		R	External Ch0 Offset
	...		—	—

The NI 9236 is a DSA module and as such it does not synchronize with other modules but free-runs at its own fixed rate.

Configure ADC

The NI 9236 (like the other DSA modules) can convert at various rates, controlled by the fields in the ADC conversion command.

Table 68. NI 9236 Scan List Format

Bits	Field	Description
15..10	Clock Divisor	The clock source (internal or external) is divided by one half of this value and used as the converter's oversample clock. Valid values are from 2 to 63, but the final divided clock must be between 502 kHz and 5.12 MHz. This means that only values from 5 to 51 (representing the divisors 2.5 to 25.5) are valid when using the 12.8 MHz internal clock source.
9..8	Clock Source	0b00 = 0: The OCLK pin is used as the oversample clock source. 0b01 = 1: The 12.8 MHz internal clock is used as the clock source and this 12.8 MHz is driven onto the OCLK pin. 0b10 = 2: The internal clock is used but not driven onto OCLK pin. Currently, this is the required clock setting. 0b11 = 3: Reserved.
7..0	Shunt Cal Enable <ch7..ch0>	Controls the shunt calibration switch for each of the eight channels. A logic 1 in any bit closes the switch for the respective channel, while a logic 0 opens the switch.

Table 69. NI 9236 Calibration Data

Data Rate	Clock Divisor	Clock Source	Configure ADC	Oversample Clock Rate
10.000 kS/s	000101	10	0x1600	5.12 MHz
8.333 kS/s	000110	10	0x1A00	4.27 MHz
7.143 kS/s	000111	10	0x1E00	3.66 MHz
2.500 kS/s	010100	10	0x5200	1.28 MHz
1.613 kS/s	011111	10	0x7E00	825.8 kHz
1.250 kS/s	101000	10	0xA200	640.0 kHz
0.980 kS/s	110011	10	0xCE00	502.0 kHz

NI 9236 Calibration Data

The NI 9236 has eight input channels for measuring strain. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

There is also a shunt measurement value which is not used during normal operation. The calibration data is stored in an U32 array, though each Offset field (subindex 1, 4, 7, etc) should be interpreted as a signed value.

Table 70. NI 9235 Calibration Coefficients

Coefficient	Representation
LSB Weight	Unsigned
Offset	Signed
Shunt	Signed

The calibration coefficients are used with the following equation to generate corrected data:

$$Nominal\left(\frac{V}{V}\right) = Binary_{Data} \times LSB_{Weight} \times 1e-13 - Offset \times 1e-7$$

The resultant calibrated reading is a ratio between the bridge input voltage and the excitation voltage, termed V_r. However, typical quarter bridge measurements are ultimately denominated in strain, which require not only conversion in the strain equation, but also the acquisition and use of an unstrained measurement, as explained below.

Due to initial tolerances in all of the bridge elements (but primarily of the gage itself), the module reading will be nonzero even when the gage is in an unstrained state. If handled correctly, this is not a source of inaccuracy, however, because strain measurement is inherently a delta measurement. A fundamental element of strain measurement involves the capture of this unstrained measurement, which is analogous to the cold junction measurement of a thermocouple measurement system. The strain equation is:

$$strain(e) = \frac{-4(V_{r-st} - V_{r-unst})}{GF \cdot [(1+2) \cdot (V_{r-st} - V_{r-unst})]}$$

where V_{r_st} and V_{r_unst} are the strained and unstrained readings, respectively from the module.

NI 9237

The vendor configuration extensions for the NI 9237 are listed in Table 71.

Table 71. NI 9237 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R/W	Configure Module, default = 0x00060000
0x2100	0	ARR:U16	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

As a DSA module, the NI 9237 does not synchronize to other modules and free-runs at its own fixed rate.

NI 9237 Configure Module

This module is set to maximum speed and configured for Full Bridge Mode for all channels by default.

Table 72. NI 9237 Scan List Format

Bits	Field	Description
31..23	Reserved	—
22..18	Clock Divisor	The NI 9237 divides the clock source (internal or external) by this value and uses it as the converters' oversample clock. The data rate is equal to 1/256 times this oversample clock frequency. The final data rate must be between 391 kS/s and 52.734 kS/s. This means that while all values from 1 to 31 are within the specified operating range when using the 12.8 MHz internal clock source, for external clock sources of more than 13.5 MHz or less than 3.1 MHz the valid divisors are limited to those that provide data rates within the specified range.
17..16	Clock Source	—
15..12	Shunt Cal Enable <ch3..ch0>	Controls the shunt calibration switch for each of the four channels. A logic 1 in any bit closes the switch for the respective channel, while a logic 0 opens the switch.

Table 72. NI 9237 Scan List Format (Continued)

Bits	Field	Description
11..8	Half Bridge Enable <ch3..ch0>	Controls the half bridge completion option for each channel. Enabling half bridge completion for a channel disconnects the negative signal input pin from the rest of the circuit, and uses an internal voltage equal to the midpoint of the excitation voltage as the negative input to the rest of the circuit. A logic 1 in any bit enables half bridge completion for the respective channel, while a logic 0 disables it.
7	Reserved	—
6..4	Excitation	Sets the excitation voltage setting. All channels share the same excitation voltage. 0b000 = 0: 2.5 V, The OCLK pin is used as the oversample clock source. 0b001 = 1: 3.3 V, The 12.8 MHz internal clock is used as the clock source and this 12.8 MHz is driven onto the OCLK pin. 0b010 = 2: 5.0 V, The internal clock is used but not driven onto OCLK pin. Currently, this is the required clock setting. 0b011 = 3: 10.0 V, Reserved. 0b1xx = 4..7: External Excitation.
3..0	Offset Cal Enable <ch3..ch0>	Controls the offset calibration mode. Offset calibration mode disconnects both signal input pins and forces the channel inputs to zero volts, enabling measurement of the channel's offset voltage. A logic 1 in any bit enables offset calibration for the respective channel, while a logic 0 disables it.

NI 9237 Example Data Rates

Example data rates use a 12.8 MHz clock source.

Table 73. NI 9237 Example Data Rates

Data Rate	Clock Divisor	Clock Source	Rate Byte	Oversample Clock Rate
50.000 kS/s	00001	10	0x06	12.80 MHz
25.000 kS/s	00010	10	0x0A	6.40 MHz
16.667 kS/s	00011	10	0x0E	4.27 MHz
12.500 kS/s	00100	10	0x12	3.20 MHz
10.000 kS/s	00101	10	0x16	2.56 MHz
6.250 kS/s	01000	10	0x22	1.60 MHz
5.000 kS/s	01010	10	0x2A	1.28 MHz
3.333 kS/s	01111	10	0x3E	853.3 KHz
2.500 kS/s	10100	10	0x52	640.0 KHz
2.000 kS/s	11001	10	0x66	512.0 KHz

NI 9237 Calibration Data

The NI 9237 has four channels. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U16 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 74. NI 9237 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	pV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{corrected}(V_{raw}) = V_{raw}(bits) \times \left\{ LSB_{weight}\left(\frac{pV}{bits}\right) \times 10^{-13}\left(\frac{V}{pV}\right) \right\} - Offset(pV) \times 10^{-8}\left(\frac{V}{nV}\right)$$

NI 9263

The vendor configuration extensions for the NI 9263 are listed in Table 75.

Table 75. NI 9263 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9263 Calibration Data

The NI 9263 has four channels with a nominal range of ±10.7 V. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 76. NI 9263 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	nV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{desired}(Code) = Code \times LSB_{weight}\left(\frac{nV}{bits}\right) \times 10^{-9}\left(\frac{V}{nV}\right) + Offset(nV) \times 10^{-9}\left(\frac{V}{nV}\right)$$

NI 9264

The vendor configuration extensions for the NI 9264 are listed in Table 77.

Table 77. NI 9264 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	1	ARR:U32	—	Calibration = 16
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9264 Calibration Data

The NI 9263 has four channels with a nominal range of ±10.5 V. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 78. NI 9264 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	pV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{desired}(Code) = Code \times LSB_{weight}\left(\frac{nV}{bits}\right) \times 10^{-9}\left(\frac{V}{nV}\right) + Offset(nV) \times 10^{-9}\left(\frac{V}{nV}\right)$$

NI 9265

The vendor configuration extensions for the NI 9265 are listed in Table 79.

Table 79. NI 9265 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R	Error Status, sent as 8-bit PDO
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9265 Error Status

Each channel has open loop detection circuitry that reports an error whenever the load is disconnected and the current is set to a value higher than 0 mA. On the cycle after the error is reported, it is (internally) automatically acknowledged.

NI 9265 Calibration Data

The NI 9265 has four channels with a nominal range of 0 to 20.675 mA. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 80. NI 9265 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	pA/LSB
Offset	Signed	pA

Use the calibration coefficients with the following equation to generate corrected data:

$$I_{desired}(Code) = Code \times LSB_{weight}\left(\frac{pA}{bits}\right) \times 10^{-12}\left(\frac{A}{pA}\right) + Offset(pA) \times 10^{-12}\left(\frac{A}{pA}\right)$$

NI 9269

The vendor configuration extensions for the NI 9269 are listed in Table 81.

Table 81. NI 9269 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2100	0	ARR:U32	—	Calibration = 16
	1		R	Ch0 Offset
	2		R	Ch0 Gain
	3		R	Ch1 Offset
	...		—	—
	8		R	Ch3 Gain
	9		R	External Ch0 Offset
	...		—	—

NI 9269 Calibration Data

The NI 9269 has four channels with a nominal range of ±10.7 V. Each channel has an associated LSB weight, which is the number of volts per bit, and an offset, which is the number of volts per bit measured when the inputs are grounded.

Note LSB weight is referred to as Gain in the object dictionary.

The calibration data is stored in a U32 array, though each Offset field (subindex 1, 3, 5, and so on) should be interpreted as a signed value.

Table 82. NI 9263 Scan List Format

Coefficient	Representation	Units
LSB Weight	Unsigned	nV/LSB
Offset	Signed	nV

Use the calibration coefficients with the following equation to generate corrected data:

$$V_{desired}(Code) = Code \times LSB_{weight}\left(\frac{nV}{bits}\right) \times 10^{-9}\left(\frac{V}{nV}\right) + Offset(nV) \times 10^{-9}\left(\frac{V}{nV}\right)$$

NI 9401

The vendor configuration extensions for the NI 9401 are listed in Table 83.

Table 83. NI 9401 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	U32	R/W	Nibble direction control, default = 0

NI 9401 Direction Control

Table 84. NI 9401 Scan List Format

Bits	Field
1	0: data bits <3..0> as input 1: data bits <7..4> as output
0	

Note Both the input and output bytes are transmitted in the PDO regardless of the direction control; only the relevant bits are connected to the I/O pins.

NI 9402

The vendor configuration extensions for the NI 9402 are listed in Table 85.

Table 85. NI 9402 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	U32	R/W	Line direction control, default = 0

NI 9402 Direction Control

Table 86. NI 9402 Scan List Format

Bits	Field
3	0: data bit as input 1: data bit as output
2	
1	
0	

Note Both the input and output bytes are transmitted in the PDO regardless of the direction control; only the relevant bits are connected to the I/O pins.

NI 9403

The vendor configuration extensions for the NI 9403 are listed in Table 87.

Table 87. NI 9403 Vendor Configuration Extension

Index	Sub	Type	R/W	Description
0x2001	0	U32	R/W	I/O direction control, default = 0

NI 9403 Direction Control

The direction control field has one bit for each I/O pin, with bit 0 matching channel 0, and so forth. 0 in the direction control indicates that I/O is an input; 1 indicates an output.

Note Both the input and output data is transmitted in the PDO regardless of the direction control; only the relevant bits are connected to the I/O pins.

NI 9476

The vendor configuration extensions for the NI 9476 are listed in Table 88.

Table 88. NI 9476 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2002	0	U32	R	Error Status, sent as 8-bit PDO

NI 9476 Error Status

If a channel over-current occurs on any of the 32 channels, the corresponding bit in error status field is set to inform the user.

Errors are automatically internally acknowledged on the cycle after the error is reported.

NI 9478

The vendor configuration extensions for the NI 9478 are listed in Table 89.

Table 89. NI 9478 Vendor Configuration Extensions

Index	Sub	Type	R/W	Description
0x2001	0	U32	R/W	Current Limit Select
0x2002	1	U32	R	Error Status A, sent as 16-bit PDO
	2	U32	R	Error Status B, sent as 16-bit PDO
0x2003	1	U32	R	Error Overtemp, sent as 8-bit PDO
0x2004	1	U8	R/W	Limit A
	2	U8	R/W	Limit B
0x2005	0	U8	R/W	Refresh Period

Current Limits and Selection

Each of the 15 channels has 2 bits represented in index 0x2001 “Current Limit Select”, with channel 0 controlled by bits 0 and 1.

NI 9478 Direction Control

Table 90. NI 9478 Scan List Format

Bits	Field
31..30	0: Limit A 1: Limit B 2: No Limit 3: (no charge)
29..28	
...	
1..0	

The current limits are set in index 0x2002 sub-indices1 (Limit A) and 2 (Limit 2). The current limits are 8-bit unsigned integers in increments of 20 mA (1 = 20 mA, 2 = 40 mA, and so on).

Error Status and Overtemp

The two error status fields each hold 16 bits of data (one bit per channel, with bit 0 for channel 0). The error status bits in 0x2002.1 are for Limit A reporting. Bits 0x2002.2 are for Limit B reporting.

Errors are reported for at least one cycle and are automatically cleared by the module when appropriate.

The Error Overtemperature field has seven bits to ignore and one bit (bit 0) that when set indicates that the module in an over-temperature condition.

Bits	Field
7..1	Reserved
0	Overtemp

Refresh Period

This is the period over which output values that may have experienced an over-current condition are re-enabled. An eight byte value in 10 µs is listed in the following table.

Value	Description
0	Infinity (no refresh)
1	Invalid value
2..255	20 to 2,550 µs refresh period

NI 951*x*

Refer to the *NI 951x C Series Modules Object Dictionary*, available from `ni.com/manuals`, for NI 951*x* C Series drive interface module object dictionary entries.

C Series Modules with No Configurable Options

The supported C Series modules with no configurable options are as follows:

- NI 9375
- NI 9411
- NI 9421
- NI 9422
- NI 9423
- NI 9425
- NI 9426
- NI 9435
- NI 9472
- NI 9474
- NI 9475
- NI 9477
- NI 9481
- NI 9485

Where to Go for Support

The National Instruments Web site is your complete resource for technical support. At `ni.com/support` you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at `ni.com/support` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

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Czech Republic 420 224 235 774, Denmark 45 45 76 26 00,
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Germany 49 89 7413130, India 91 80 41190000, Israel 972 3 6393737,
Italy 39 02 41309277, Japan 0120-527196, Korea 82 02 3451 3400,
Lebanon 961 (0) 1 33 28 28, Malaysia 1800 887710,
Mexico 01 800 010 0793, Netherlands 31 (0) 348 433 466,
New Zealand 0800 553 322, Norway 47 (0) 66 90 76 60,
Poland 48 22 328 90 10, Portugal 351 210 311 210,
Russia 7 495 783 6851, Singapore 1800 226 5886,
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